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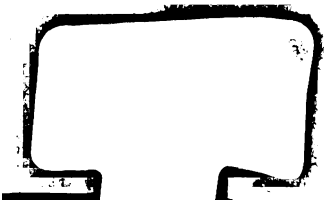

Institution

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THE

TRANSACTIONS

OF THE

INSTITUTION OF CIVIL ENGINEERS

OF IRELAND.

VOL. III.

DUBLIN:
SAMUEL B. OLDHAM, 8, SUFFOLK-STREET.
LONDON: JOHN WEALE, HIGH HOLBORN.
MDCCCXLIX.

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Note: The Editor of the Transactions is directed to state, that the Authors alone are responsible for the facts and opinions expressed in their several communications.

TRANSACTIONS

OF THE

INSTITUTION OF CIVIL ENGINEERS

OF IRELAND.

[November 9th, 1847.]

Description of the means adopted for unwatering works of river drainage; by SAMUEL U. ROBERTS, ESQ. Member.

THE cost of unwatering, forms a large item in the expenditure on works of river drainage; under the most judicious management it costs, on an average, from eight to ten per cent. of the whole outlay. The mode of executing it in an economical manner, is therefore of much importance; and as it is only a temporary work, and one which will not live in form (though it will in outlay) after the Engineer, it is for this reason often executed with implements unsuited to its economical performance.

The general method adopted for unwatering river courses, which are to be deepened and improved for the purpose of drainage, is to divert their waters down a back drain by a head dam, and discharge them again into the river course, below the site of the proposed works; in doing this, advantage is taken, where possible, of con-

verting the existing drains into back drains, and this part of the work is often effected at a small expense.

With the exception of those cases where a rapid fall exists in the river, it is necessary to form tail dams, over which the waters from the intermediate portion of the river course are raised, to admit of the excavation being sunk to the proper depth.

Throughout those districts upon which I have been engaged, about two feet in depth, on an average, of the cutting, has been below the lowest level, which the water in the lower, or finished portion of the river course, could be reduced to.

Assuming that the average depth of excavation in a river channel is five feet, about one-third of the whole quantity will (under the circumstances I have detailed,) be below water level; and the execution of this part of the work, from the difficulties that sometimes exist in unwatering it, forms a very serious item in the whole cost of the measure, sometimes doubling the expense of the excavation of the lower two feet in depth.

There are two circumstances, which should in every instance influence the Engineer in the selection of the means he adopts for unwatering works—one, is the length of time during which that operation is to be continued at any fixed point; the other, the lift or height to which the water is to be raised.

If such work is of short duration, and can be executed by manual labour, it would be very injudicious to incur the expense of fixing machinery, the cost of which would not be commensurate with the economy of its power. Under such circumstances I have found the most suitable implements to be the swing scoop, the lever pump, the hand scoop, the chain pump, and the suction pump.

The "swing scoop," which is suited to a lift of from one foot to eighteen inches high, is formed of sheet iron, and is suspended by a rod capable of being adjusted, as to length, from a tripod stand; it is worked by two men, one standing upon each side.

The "lever pump" consists of a long trough or box, moveable upon an axle, placed upon the head of the dam, over which the water is to be raised, the other end being attached to the arm of a lever working on a fulcrum, which passes through the heads of the uprights supporting it; in the bottom of that end of the box, which is plunged into the water in the well, is a large valve, which admits of the pump filling in a short space of time.

The "chain pump" is adapted to a lift, not exceeding five feet; but it is so overloaded with friction, that it cannot under any circumstances, be rendered an economic machine, though it is in some cases very effective; for instance, where running sand would prevent a lifting pump being used.

For lifts exceeding four feet, the common "suction pump" is the most effective implement, it is simple and economic in its construction, easily fixed, moved, or repaired, and may be worked according to the dimensions, with large or small powers.

The quantity of work which the implements I have now described are capable of performing with manual labour, and its cost, I have ascertained from my own observations to be as detailed in the following Schedule.

SCHEDULE.

IMPLEMENT.	Height to which water is raised.	Number of men employed, including the necessary relay.	Cost per day. S.	Cost per day. D.	Cost per hour. S.	Cost per hour. D.	Actual quantity of water discharged per hour.	
Swing Scoop.	1 foot.	3 men	3	9	0	$4\frac{1}{2}$	1800	One cubic foot each stroke, 30 strokes per minute, = 1800 cubic feet discharged per hour, two men working, one man relay.
Lever Pump.	2 feet.	3 and 1 boy	4	6	0	$5\frac{4}{5}$	1440	Twelve cubic feet of water each stroke, 2 strokes in a minute, and lift 24 cubic feet in a minute, 1440 per hour, two men to work, and one boy to weight the trough when plunging, one man relay.
Hand Scoop.	3 feet.	2 men	2	6	0	3	434	One Scoop, discharge $7\frac{1}{4}$ cubic feet per minute, 3 feet high, one man working, one man relay.
Chain Pump.	5 feet.	9 men	11	3	1	$1\frac{1}{2}$	1560	Length of chain pump, including Buckets, 50 ft. Do. Spaces occupied by Buckets, 7 Conduit for discharge of water, 43 Available area of pump, 49.0 inches, which multiplied by 43 feet by the number of revolutions in a minute (4·5 of 3) gives the discharge at 35 cubic feet per minute, deducting $\frac{1}{4}$ for leakage, will be 26 cubic feet, the actual discharge per minute by 60 = 1560 cubic feet discharged per hour.
Suction Pump	6 feet.	8 men	10	0	1	0	1400	Six-inch square pump, worked by four men, four men relay, 28 strokes per minute raised 325 cubic feet in fifteen minutes, = 1400 cubic feet per hour.

So far, I have described the means I have used of unwatering works, when circumstances would not warrant the cost of fixing machinery; but when works of a tedious nature, such as the removal of a rocky shoal, or laying the foundations of a bridge, are to be executed, for the economical performance of the work, it is often desirable to fix the pumps, and work them by other means than that of manual labour, and a ready agent is always at hand, in the river turned into the back drain.

Plates 1 and 2, show the manner in which I have applied the turbine to this purpose; the model I have prepared with the view of illustrating more clearly its construction and mode of working, and to show how readily it may be applied as a motive power to any machinery.

Before describing the construction and effect of the turbine which I have used, I shall briefly allude to the facts and principles laid down by Professor Rhulman, in his work which has been so clearly translated by Sir Robert Kane.

The practical rules for the construction of turbines given by Rhulman, appear to have been founded on experiments and observations made by him during an inspection he made of those turbines then erected, and at work on the Continent.

The calculations are elaborate. The available quantity of water flowing per second, and the total fall having been ascertained, the first calculation required is—

The velocity with which the water enters the direction of the guide curves.

The radius of the inner edge of the wheel is then determined, and its velocity.

The number of revolutions which correspond to its greatest effect.

The determination of the angle, which a thread of water issuing from the guide curve apparatus forms, with the radius of the inner periphery of the wheel.

The diameter of the external periphery of the wheel, and lastly—

The construction, number, and height, of the paddle boards.

No definite rule is given for the form of the guide curves.

There is no doubt from the experiments made by Fourneyron and others, that the useful effect of the turbine amounts to at least seventy per cent. of the theoretical force of the stream of water; and when it is considered, that the proportion of the theoretical power of the stream

of water can be economised, no matter how great or small the fall is, or how deeply the turbine wheel is immersed in water so long as a head remains, the great utility of the machine becomes apparent, and it at once occupies the first place in the rank of water wheels.

A careful examination of the model will give a very clear idea of the principle on which it works, and what should be the relative proportions of many of its parts.

It is evident the inner periphery of the wheel, and the height to which the sluice is raised, must be of such dimensions as will admit of the discharge of water available for working the turbine, without any diminution of its head, the guide curves deflect the water from its vertilineal course, which, by its centrifugal force, creates a pressure on the paddles of the wheel, that gives it a rotatory motion, and the curve of the paddle boards will in a great measure depend on the velocity of the wheel.

As I have already observed, before determining the dimensions of a turbine, there are two quantities which must be ascertained with correctness—one, the fall ; the other, the available supply of water. The rules laid down by Professor Rhulman will then enable the proportions of the other parts of the turbine to be determined.

In making the plans for the turbine used on the works of the river Glyde, under the directions of the Drainage Commissioners, as represented in plates 1 and 2, I found the minimum available supply of water to be ten feet per second, and the fall four feet ; and from these quantities I calculated that the external diameter of the turbine wheel should be 4.16 feet, the internal 2.38 feet, the number of paddles twenty, and the greatest effect obtained when the sluice was raised, two and half inches. Under these circumstances, the power was calculated at 3½ horse power,

the dynamic unit of a horse power being 33000 lbs. raised one foot in a minute; but as it was desirable to make the turbine as portable as possible, to admit of its being easily removed from one part of the works to another, I contracted these dimensions, and made the external diameter of the wheel only three feet, and the internal, one foot nine inches, and the sluice was raised two and a half inches.

The number of revolutions made by this turbine was seventy-eight per minute; and by the interposition of cog wheels, the relative diameters of which were three to one, the pumps gave twenty-six strokes per minute. The height to which the water was raised was ten feet; and I found this turbine raised one hundred and forty-four cubic feet of water ten feet high per minute, which was equivalent to 2.65 horse power, and thus economized sixty per cent. of the effective discharge of the stream.

This was the maximum quantity of work performed; it was not generally necessary to work it up to this power, as two twelve inch pumps, discharging seventy-five cubic feet of water per minute, were sufficient to keep the works dry. The turbine I have described was, however, capable of performing the duty I have now mentioned, and it would I am sure, have worked up to the power Fourneyron ascribes to it, namely, seventy per cent., if I had not contracted the dimensions determined by Rhulman's theory.

The plates represent the turbine working two pumps, and raising water seven feet six inches. As floods sometimes reduced the available falls from four feet to less than three feet, the minimum power was not calculated to perform greater work, nor did the exigencies of the case require it.

The cost of this turbine, the connecting gear, and the

two pumps fixed in their positions, including every expense, was £50.

It worked the power of twelve men, day and night, for above two hundred days. Allowing 1s. 3d. a day to men, and 1s. 6d. a night, the daily cost of pumps performing similar work, would have been £1. 13s.; and this for two hundred days, would amount to £315. Allowing £50. for wear and tear of pumps, cost of oil, attending and fixing at different sites, &c. in working, the saving effected by the adoption of this machine, was at least £265.

The saving I have detailed, is that effected on a drainage measure carried on under my own superintendance. If the turbine was required to work up to its full power, the saving of expense would, of course, be proportionably greater.

I am aware that a vast number of instruments have been invented for the purpose of raising water, but the result or effect of those I have described, have come under my own observations, and have appeared to me to be practically useful in the execution of such work.

I trust my having brought the matter before the Institution, may turn the attention of some of its members to the subject, which I have no doubt will be highly beneficial to the profession to which so many of us belong, and in which all are so much interested.

[December 14th, 1847.]

Description of Clock with a Registering Machine attached, by RICHARD SHARP, ESQ., M.R.I.A., Associate.

IT would not appear strange, in this age of mechanical wonders, if the science of Horology had received a great impulse and improvement, as men's minds have been occupied so much of late in bringing to perfection almost every branch of mechanical manipulation; and as also the requirements of science seem to demand more perfect instruments than formerly; but strange as it may appear, such is not the case. Although there have been men, for many years in the profession, of great ability and practical experience, they have not made any improvement worthy of commendation; and where some have departed from the well known and ordinary systems, they have almost invariably been obliged to return to the inventions of such men as Graham, Arnold, or Errinshaw. Thus showing how little there has been left to be desired in the practical excellence of instruments, which are fully equal to all that is required of them, in the advanced science of the present day.

But if we descend from the higher branches of the art, we will find that much has been done of late in the perfection of registering apparatus for various purposes, which are in a great measure connected with Horology, and which form links in the chains of usefulness, from being connected with scientific researches and results, thus becoming interesting and valuable, though in themselves requiring but a small amount of ingenuity in their construction.

Having been engaged in the execution and invention of

many such instruments, it occurred to me that they might be usefully applied to many purposes not immediately scientific; and having been required a short time since, in the course of business, to construct a "Noctuary," or Watchman's Tell-tale, (as it is called,) it appeared to me that a much more perfect instrument than the one in common use could be made, by putting a simple addition to an ordinary clock, and also by this means it could be made useful for many purposes not heretofore contemplated.

This marginal drawing represents the simplest form of the invention, as a Noctuary, or Watchman's Tell-tale, the use of which is to tell whether a man who has been placed in charge of premises at night, has been attentive to his duty.

The mechanism and manner of using it is very simple, To an ordinary clock dial, there is added forty-eight projecting pins, in the position represented in the sketch. These pins project from the face of the dial about one quarter of an inch, so as to permit the hour hand of the clock to move freely over them, and the hand occupies fifteen minutes in passing from one pin to the next. Any one of these pins is free to be pushed level with the dial, at such time as the hand is over it, which is done by means of the hand having sufficient freedom, that it can also be brought level with the dial by means of a pull string, which, when relieved, allows the hand to return to its

original position by the action of a spring, but leaves the pin pushed in, thereby making a registry of the time the hour hand was acted on, each pin representing a particular period of time.

Let it be supposed that a watchman had been desired by his employer to pull the string which is attached to the clock every quarter of an hour, for the purpose of notifying his presence, and that he does so; then, each pin on the dial will be level in succession; but should he neglect any one interval, the pin representing that time, will remain standing out as a memorial against him, thereby giving the employer a perfect check over him.

To make these same pins available for another occasion there is a mechanical contrivance in the clock, which at the end of every twenty-four hours, instantly replaces them in their original position, thereby giving an interval of twelve hours for the examination of the previous registration.

This second representation shows the application of the Noctuary to the same purpose as the former, with the additional advantage of the registration being continuous for a week, giving the proprietor (should he be absent for some days,) the means of knowing the attention of the watchman.

This is accomplished by increasing the number of pins seven times more in number than the former, which is

easily done by enlarging the circle as in the representation. The hand which acts on the pins is distinct from the hour hand, and makes but one revolution in the week, and being the same colour as the dial, is not perceivable.

It is also acted on by a pull string (as described in the former method,) which gives the desired registration.

The third marginal drawing represents another arrangement, by which intervals of a minute can be registered, and would be valuable for scientific experiments not requiring a closer approximation to time. In this, the hour hand acts on the pins alone.

But should it be required to have an instrument that would register the hour, minute, and second of the time of any particular occurrence, it could be effected by having a series of pins to be acted on by each hand of the clock. One of the great advantages attained by this invention is, that the additional mechanism required for these objects, does not in the least interfere with the most delicate action of the clock, the movements of which can be as truly depended upon with this addition as without it.

A short account of the fall, during a violent storm, of part of a roof in progress of erection over the Dublin Terminus of the Midland Great Western Railway, by GEORGE W. HEMANS, ESQ., M.R.I.A., Member.

As it is not very usual to record, by papers, the description of any accident occurring on public works, I must apologise for doing so, at the same time, however, observing that I think much instruction may be derived from a correct investigation of such events, and their causes; and I believe that many a mishap might be avoided in future, if engineers and mechanics could be persuaded occasionally to recount their failures as well as their successes.

The roof in question is one of unusually large dimensions, novel in construction as well as in material, and the design of it as approved and adopted by me, is one which reflects credit on the highly respectable contractor who undertook the work, and who, it is to be regretted, will be a sufferer to some amount, by a little carelessness on the part of his men in the process of erecting the principals.

I believe a model of the roof was exhibited some time ago at this Institution. The total length is four hundred and seventy-five feet, and width, one hundred and twenty, divided into two spaces of sixty feet each, the roof resting on walls at either side, and on columns in the centre; a skylight, twenty feet broad, of sheet glass, runs continuously along the ridge of each half of the roof.

The centre columns are sixty-two feet six inches apart, and are connected by flat arches and gutter plates. The whole structure, with the exception of the columns, gutter

plates, and tie washers and sockets, is composed of rolled iron of a very superior quality.

The principals, which indeed are the only rafters, are thirty eight in number to each half roof, and they divide the total length into spaces of twelve feet six inches. They are formed of what is called rolled iron "deck beams," from the use of such a form in the beams of iron ships; the section is very strong and judiciously designed in the form of a double flanched rail with broad base. One of the chief points requiring skill in the construction of this roof, is the perfecting of the weld when two or more pieces are joined together to form a rafter; the shape of the cross sections of the iron, renders this weld a difficult one to make, and very skilful workmen had to be employed for the purpose. The connecting arches between the columns are made of the same kind of "deck beam," strengthened by lattice work in the spandles; and notwithstanding their flatness and great span, they are exceedingly strong and rigid. The gutters on the walls and columns are continuous troughs of cast iron, in lengths corresponding to the spaces between the principals, twelve feet six inches, and are secured at each of those points to cast iron beds, let into heavy anchor stones on the side walls, and bolted to the centre columns. The rain water is carried down through the hollow of each column, and at corresponding points by pipes let into the walls, to the drains below.

The cover or sheeting of the roof is composed of corrugated rolled iron, converted, by a patent process of galvanism, into a compound of iron and zinc; the zinc is not only precipitated on the surface of the iron sheet, but the Patentees also claim the merit of producing absorption of the zinc into the pores of the iron, thereby rendering

the latter inaccessible to oxidation; a specimen of the sheeting is herewith presented. It is almost needless to observe, that it is necessary that the rivets employed to connect these plates, should be also of galvanized metal, as the rust would otherwise soon destroy the roof through them. The corrugated form gives a great addition of strength to these plates, and it is fully expected that the galvanizing process will entirely obviate oxidation, and consequently the necessity for painting the plates periodically, which is a great source of expense in common iron roofs.

In order to avoid the ill effects of expansion in so great a surface of plates, it has been found necessary not to connect the sheeting to the rafters at all, sideways, but only to rivet the stripes to each other, and at the top and bottom only of the whole surface to the rafter; this admits of rise and fall in the arch, which the sheeting describes, independent of the rafter; and I expect that any lateral expansion may resolve itself into this, or perhaps disappear through the corrugations.

As a general description of the roof, it only remains to add to the above notes, that the ties are all of wrought iron round and flat rods carefully fitted in the first instance, with no adjusting screws, and the frame of the skylight is also of wrought iron.

I will now proceed to a description of the accident which occurred during the erection of this roof, first stating that all traces of such an occurrence have been a good while removed, and that the roof is now progressing again very fast towards completion, and is in a most satisfactory state in every way.

The erection was conducted in the following manner: the end centre arch next the cross wall was tied by a

strong back plate and bolts into that wall, from which it springs, the column next to it being adjusted to connect it with, and thus the next adjoining arches and columns, one after another, completed the line of centre supports which were of course stayed transversely, by scaffolding poles. The junction plates of the gutters, from which also the rafters spring, being securely leaded to the anchor stones with lewis bolts, and the gutters being laid and jointed both on the walls and on the centre line of columns, each half rafter was hoisted on the scaffolding, bolted and leaded to its springing socket, and connected in the centre to the meeting sockets of the louvre frame.

The next process was the pulling in the tie rods and struts, and finally connecting the principals one with another, by the parallel bars of the skylights, none of the cover or sheeting being yet commenced. As soon as the ties and parallel bars were fixed, the scaffolding under each principal was removed to the next one in continuation.

In this manner, about twenty-five of the rafters were erected on each side, and the whole centre line of columns and arches complete, when the stormy weather of the winter months began to prevail. It must be observed, that the position of the roof was now a series of parallel frames of iron, standing on edge, twelve feet six inches apart, and connected rigidly at foot by the springing sockets and line of gutters, but very lightly tied at top, by small bars of angle iron; the principals were thus in a perfect state for resisting any downward pressure, but had little or nothing to secure them from turning over sideways, as there is no diagonal bracing in the design of the roof, the necessity for which is superseded by the rigidity of the corrugated plates when rivetted together. There was, therefore, nothing at this time, on one side at least, calcu-

lated to prevent the whole structure from heeling over. On the 6th and 7th of last month, there were some very violent gales, and on the morning of the 7th, about ten o'clock, a message came to me, that the whole roof had been blown down. I immediately went to the Station, and found that a great deal of damage had been done, and the part of the roof left standing, appeared in imminent danger. Twenty-three of the large rafters on the west half-roof had been blown down, one over the other, like a pack of cards, the whole of them had snapped their sockets across, and many hung suspended by the tie rods, between the side wall and centre columns.

There happened to be, fortunately, a very strong temporary wooden shed under this part of the roof, a portion of which resisted the concussion and weight of the rafters falling on it, and by preventing their further descent, saved the other half of the roof, which, with the centre line of columns and arches, would have been dragged down but for this support.

At the end of the temporary shed, the shock upon the rafters seems to have been more violent, as there the anchor stones, which are of great weight, were completely dragged off the wall, and fell upon the shed, bearing down all before them; the gutter plates which connected all the anchor stones one with another, were of course broken off at the stones that fell, and the line of gutters on the top of the wall presented a very singular appearance.

The wall on this side consists of alternate piers and openings, and a great many of the piers were strained, cracked, and out of plumb, from the drag upon them of such of the rafters as still hung by the ties to the anchor stones, half off and half on at the top.

On the east half of the roof one tie only broke, and five

of the rafter beams at the sockets; one of the centre arches was dragged considerably out of the straight line, and the first column cracked across the neck. I attribute the saving of this half of the roof entirely to the simple precautions having been taken, of putting up a couple of scaffolding poles, slantways, against one of the ribs, in the centre of that side, and these two poles alone prevented all the east side rafters from turning over. It was most fortunate that no person was injured in the slightest degree by the fall of the roof, and this circumstance greatly alleviated the annoyance of the accident. The day being Sunday, it was some time before men could be got together, and meanwhile the east side of the roof was straining fearfully, and I expected its momentary fall, as the violent gale continued. As soon as the carpenters and men arrived, all the poles that could be collected were set up, to strut and shore the standing part of the roof and centre columns; many light spars were lashed as diagonal braces, across the ribs, and before dark, several hundred struts were up, and the whole was considered safe for the night, which continued very stormy.

By the evening of the following day all the debris of the fall was removed, and the recommencement of the structure arranged on a safer basis; the centre line of arches was skilfully brought back to a straight line, the cracked column secured by a solid piece let into the hollows, and the brick piers, which regained the vertical position, when relieved of the weight hanging from them, were so little injured, that I decided on underpinning the cracked parts with fresh brick in cement, to recover the bond of the whole. The piers being all connected by very flat arches, the taking down of one only would probably have required the rebuilding of the whole.

The plan now in progress for the re-erection of the roof is to sheet over the ribs as they proceed, beginning at the south end, by which means, the rivetted plates connecting every rib, they cannot leave the vertical position, and I have every confidence in its shortly presenting an admirable specimen of a railway shed roof on a large scale.

It is satisfactory to know, that after describing so complete a scene of destruction as I have done, I can say that I believe the pecuniary loss to the contractor will be comparatively very trifling, probably not exceeding £300; and I firmly believe that his loss would have been as many thousands, but for the two diagonal poles which kept up the east half roof and the centre line of columns and arches. I purpose presenting complete sketches to illustrate this paper, and conclude by again apologizing for taking up the time of the Institution by this narrative of what many of our experienced members may consider a comparatively simple occurrence.

N.B.—Since the above account of the accident was written, the roof in question has been completely and successfully finished, and having been inspected by some of the most eminent engineers in England, it has, I am happy to say, met with their general approval, so much so, that a similar one on a larger scale has been adopted by Mr. Locke for the new terminus of the London line at Liverpool, this latter is to be of the enormous span of one hundred and fifty-four feet in one arch, and this will be, I believe, the largest in the world. The light and elegant appearance of this kind of roof, combined with its economy and convenience, getting rid by its large spans of numerous intermediate columns, and besides being fire proof in the fullest sense, rendering the continual use of paint

unnecessary, give it, in my opinion, a fair claim to general use in passenger sheds for railways. A complete set of drawings of this roof are presented to the Institution.

Memoranda in reference to Blasting Operations on the 5th, 8th, and 29th October, 1847, *for the removal of an old mill at "The Cuts" near Coleraine, in connexion with the works of the Lough Neagh Drainage and Navigation Measure,* by CHARLES S. OTTLEY, ESQ. A.M., M.R.I.A., Member.

THE mill at "The Cuts" was required to be removed to admit of the improvements in the river Bann, at that place, being carried out.

Being situated by the public road side, and within a few yards of a row of houses, it was necessary to be particularly cautious in taking it down.

The building was very extensive, being ninety feet long, forty feet wide, and sixty-five feet in height.

The interior and roof had been destroyed by fire some years previously, but the walls had remained perfect, and being inaccessible from within, except with a serious expense in scaffolding, the ordinary method of taking them down from above could not be adopted.

Under these circumstances, it was determined to have recourse to gunpowder, and the result was eminently successful.

The two end quoins furthest from the road, were first undermined from the interior, and a bag containing thirty pounds of powder was placed under, being deposited in the foundation course, and about half way into the thickness of the wall.

Two fuzes having been inserted in each bag, (to ensure ignition,) the holes excavated were filled in, a layer of heavy stones being placed in the bottom, so as to close against the mouth of the chamber.

Alternate courses of clay (well rammed) and stone were then carried up to a height of four feet, and loaded on top with stone.

The surface of the ground outside the quoins was also four feet above the level of the charge.

These two shots were fired at different times, and the effects produced in each instance fully equalled the anticipations which had been formed.

The first shot brought down the quoin, and about six feet of either wall immediately adjoining it for the full height, being equal to about two hundred tons of masonry.

The second shot had a still greater effect, having brought down fully three hundred tons.

In each case the mass was perceptibly upheaved first, then tottered, and fell in fragments round about the place where it had stood.

It was remarkable that the second shot removed with the quoin a portion of the end wall furthest from it, leaving standing the intervening part, about eight feet wide, and for the full height of sixty-five feet which was afterwards thrown down by leverage.

Upon the first observation after the explosion, a portion of the quoins appeared to have remained undisturbed, but upon examination, it was discovered to be the quoin of the upper part of the building which had dropped down perpendicularly when the lower part had been removed, and occupied nearly the identical spot the removed portions had previously stood on.

The positions of the charges on the 29th, were under

portions of the side walls, separating two vertical tiers of window opes. The quantities of powder, eight pounds and twelve pounds respectively, were made thus small, both for safety and experiment.

In each case, the same process of tamping, &c. was adopted, as before described for the quoins.

The result was, that the piers were greatly shaken, and completely separated from the remainder of the building by a vertical fissure extending from top to bottom of the walls, which enabled the men, by partial undermining and a few blows of a battering ram, to bring them down.

The tamping was blown out in the two last shots, and it is believed, that if fifteen pounds of powder had been placed under the walls, instead of twelve pounds, their immmediate fall would have been secured ; but as was before observed, the very close proximity of several houses, caused the adoption of a less charge than under other circumstances might have been made use of.

The walls were three feet thick in bottom, and two feet at top, composed of superior rubble masonry with dressed quoins properly bonded, and the mortar was particularly hard and strong.

Tenders had been received for the taking down of this building in the ordinary way, the lowest of which was £70, whereas the actual cost by the agency of powder as here described, did not amount to £5., besides possessing the important advantage of expedition.

[11th January, 1848.]

An account of the Caisson Dams used in some of the works on the River Shannon; by LIEUT. COL. H. D. JONES, R.E., M.R.I.A., President.

THE President exhibited a model of the Caisson Dams which had been used under the direction of Mr. Gisborne (the resident Engineer,) for the removal of shoals on the upper Shannon.

These dams were formed of Caissons, sunk at short intervals, along the line of direction of the dam, and in the intervening spaces, rough Coffer Dams were formed in connexion with the caisson on either side. The objects sought to be accomplished by this mode of operation were economy in execution, facility in formation and removal, and expedition in construction.

The line of direction of the dam and the distances, apart of the caissons, having been decided upon, the portion of the bed of the river destined to receive the dam was cleared in the ordinary manner. The caissons which were formed of timber somewhat similar in sections to the proposed dam, properly braced, and planked on the sides and bottom, were floated and sunk in their proper positions, having been filled with puddle. Vertical grooves were formed at the four angles of the caisson, to receive the ends of the planking of the adjoining dams. Round iron bars, to act as guide piles, pointed at end, were driven at such distances apart, as were suited to the length of the planks (which were to be fixed horizontally, so as to form the sheeting of the dam) and as were required for the stability of the work.

Flat iron bars were driven in front, and within three or

four inches of the vertical bars, and the planks were fixed horizontally, as sheeting, between the piles; those abutting against the caissons being let into the grooves formed thereon, and the other ends being allowed to pass the ends of the adjoining tier of planking.

The second row of planking to form the coffer, was similarly fixed, and the vertical bars of both strongly connected at top, so as to prevent the sides from spreading; strong round iron bars were also driven in a standing direction, as stays, on the inside of the dam, and fastened to the heads of the inner upright bars, by eye bolts and cotters.

The interior of the coffer dam was then filled with puddle.

The subject of caisson dams was, in the latter part of the last session, brought under the notice of the Institution by Mr. Bevan, who had successfully used them in the removal of shoals in the river Inny. These dams were composed of a number of caissons, constructed as already described, and spaced only so far apart as the length of the planks used in the operation would admit. When the dams were sunk in their proper positions, the planks were fitted horizontally into the grooves, and the interior of the coffer was filled with puddle.

The President submitted the following report by Mr. Gisborne on the Caisson Dams used on the Shannon Works, and on the efficacy of dams constructed on the same principle, having iron piles substituted for the caissons.

"Mr. Bevan has, by the introduction of the use of the caisson dams, opened a field of experiment and enquiry to the engineer, which is particularly important at the present

moment, to the progress and execution of the large water works in operation in this country. His success in the use of these dams in removing shoals in the River Inny, induced me to have a trial of them made on the Shannon, where, in general, the greater body of water to be contended with, would better test their capabilities to support pressure, and enhance their value in proportion as they were found to resist this pressure; or at least show at what limit of head, and under what circumstances their application was beneficial in the material points of economy and saving of time.

"In the first test of the practicability of this species of damming, every opportunity was offered of bedding the caissons (two in number) properly, and laying the plank regularly; the experiment being made across the harbour at the lower end of Lough Allen Canal, where the water could be drawn off or let in at pleasure.

"A height of 6′:3″ of water was obtained without any perceptible displacement in the dam; but the Canal being made for only a five feet navigation, the head was reduced to 5′—6″ for fear the banks might be injured.

"The bottom of the harbour is composed of a soft blue clay, which hardens by exposure to the air; the puddling material was of the same description. Considerable leakage was observed under the caissons, increasing to a regular stream, although some attempts were made to staunch the places with clay. After standing for nearly twenty-four hours, the dam began to move, and in about twenty minutes the caissons heeled over, taking the coffers with them. It was observed, that the chief cause of this burst was the tendency of the caisson to allow water to pass under it, bringing into action its great power of floatation, which could not be effectually

counteracted by weighting; in the case alluded to, the caissons were each weighted with three tons of stone. Finding this difficulty arose from having a large and unwieldy piece of framework as a connexion between the coffers, and also keeping it steady in one place when once sunk into its proper position, it was thought that iron piles stayed on the inside, would prove equally strong, more easily moved about, and not subject to the most objectionable propensity of the caissons to float or heel over when leakage of any extent occurred under them. At Groses Island Shoal near Carrick-on-Shannon, a dam twelve feet in length, was made along one side of an enclosure," (similar to the model exhibited and described by the President,) "the two caissons previously experimented on, being again used in order to compare the relative strength and efficacy of the two methods adopted in connecting the caissons. The head of water the dam had to sustain, varied from 6′ : 9″ to 7′ : 0″; one of the sets of iron stays being in eight feet of water. The pit enclosed was unwatered into a lower enclosure previously completed, and kept dry for the purpose, so the defects of the dam were immediately apparent.

"Considerable leakage was observed under the caissons, which was stopped by puddling both inside and outside; had the pit been unwatered by pumping, great expense might have been incurred before the position of the leak was ascertained; and had more than two caissons been used, it is probable great difficulty would have been experienced in stopping the leakage, which, as far as these trials have shown, almost invariably occurs under them. The caissons also evinced a disposition to heel over, notwithstanding they were filled up with stones to the very top; their size rendered them very unwieldy and

difficult to sink at proper distances apart; this was particularly the case in rough weather. In one of the caissons a small side valve was made, by which means it could be filled with water, and thus assist in sinking it; but notwithstanding this and other mechanical contrivances, great loss of time and trouble attended their positioning; also from their large surface of floatation, any motion in the water rendered them liable to shift, and either strain or displace the side sheeting forming the coffer. The iron piles, on the contrary, are easily driven with a heavy sledge, and no difficulty experienced except in sinking the planks, which was subsequently obviated by means of a sliding rod of iron, as used in enclosing Derrycarne Shoal, between Lough Bofin and Lough Bodarrig; with regard to expense, the iron framework has much the advantage: taking the cost of making the coffers as equal in each case, the cost of a caisson is £6., that of the iron piles about 32s. The caisson when done with, is expensive to move from place to place, and not saleable; whereas the iron will always fetch about two thirds of its original cost. Also with the piles the breadth of the coffer may be considerable, the tendency to heeling over being counteracted by spreading out the stay, thus increasing the base at the point of support; this acts *doubly* as a saving, the cost of *putting in* the puddle and *taking it out* having to be considered in calculating the relative expense.

"From the experience thus obtained, the use of the caisson dam was deemed impracticable in an exposed situation, such as the Shoal at Derrycarne, formed by one of the Gravel Eskers, of so frequent occurrence on the Shannon, separating two large lakes, Bofin and Bodarrig. This shoal preserved in a great degree the remarkable

feature of all these Eskers, viz:—a rounded ridge on top, with very precipitous sides, so that the stanks had to be made on the edge of very deep water; added to this, there was a great scarcity of puddling material, and the length of dams necessary very great—over twelve hundred lineal feet; under such circumstances, common clay dams would have been very expensive. All the two and half inch round iron that could be obtained in Dublin, of sufficient length, was sent by canal to Derrycarne, and cut into lengths, varying from seven feet to sixteen feet according to the depth of water, and length of stay required, taking as a general rule, that the base should be equal to the depth of the water. In consequence of the exposure of the situation, and the frequent occurrence of large boulder stones, the driving of the piles and putting down the planking was attended with some difficulty. The planks were slipped down by means of a rod sliding on the upright pile, being every third plank linked together by a ring going over both pile and slide; this prevents the planks from turning or rising when once under water. Great difficulty was experienced in stormy weather to prevent the coffer from drawing the piles, and rising altogether before the puddle could be put in; this occurred repeatedly, many days' work being often made of no avail by a few hours' high wind; also at the commencement, the coffer was made too broad at bottom, the weight of puddle bursting away the iron framework, and this is an important point to be attended to in practice, for the puddle is only put in to ensure staunch ness in the dam; its weight at the bottom acts in the direction of the pressure of the head of water, increasing the tendency of the structure giving way. For seven feet depth of water, the coffer should be 3′ : 6″ at bottom, and

1′ : 9″ at top, or even less, if the material in which the piles are driven is not tenacious, as was the case at Derrycarne; no general rule can, however, be given on this point, as it depends greatly on the nature of the puddling material, staunchness being a most important requisite in the formation of the dam. Annexed is a table showing the comparative cost of common clay dams and those of coffers supported by iron frame work, in the latter case ten per cent. is included on the price of the material (iron and timber,) which is a full allowance, the planks being always saleable for wheeling, and the piles for old iron, very little wear and tear occurring on either. I may mention that the removal of these dams is very easy, either by drawing the piles or allowing the whole to burst into the enclosure by loosening the stays, in which case the planks will float, and the small quantity of puddle forced into the pit can be either scraped away or removed by dredging. The season was so far advanced when the dams were closed at Derrycarne Shoal, that it was not thought advisable to unwater the enclosure, so that I am unable to give any practical results as to their efficacy in that instance; from the exposed situation it is probable they will be subjected to a very severe test, and casualties at present unforeseen may be the result. After next summer's experience, I may again bring this subject under your notice, when I hope to add to the practical experience thus obtained, a few simple calculations and formulæ, showing the limits at which they are applicable, and the data from which their application can be rendered successful as their defects become more known. The present report is but a general outline of the practical results obtained, which are certainly satisfactory, but still showing that the working out of the principle is far from

being perfect; many improvements by mechanical contrivances could be pointed out, but practice alone can determine which of the number are really useful. From the experience obtained, I am, however, of opinion, that for a depth of water exceeding four feet, and less than ten feet, (the limit they have been tried at,) this description of dam will be found the cheapest and most expeditious in forming and removing, and if made with ordinary care, quite as strong as an earthen dam, and less likely to be affected by casualties, an unlimited power of staying being afforded from the inside."

TABLE,

SHOWING THE COMPARATIVE COST PER LINEAL YARD

OF

Clay dams and those sheeted with planks and supported by iron piles and stays.

Depth of Water.		COST PER LINEAL YARD. Clay Dams.			Sheeted dams with iron supports.			Including Ten per cent. on cost of Iron and Planks.
Ft.	In.	£.	s.	d.	£.	s.	d.	
3	0	0	1	7½	0	1	10	
3	6	0	2	4½	0	2	2	
4	0	0	3	0	0	2	6	
4	6	0	4	9	0	3	2	
5	0	0	6	0	0	4	2	
5	6	0	7	4½	0	4	5	
6	0	0	8	9	0	5	2	
6	6	0	10	6	0	5	7	
7	0	0	13	7½	0	6	8	
7	6	0	15	3½	0	7	0	
8	0	0	19	2	0	8	0	
8	6	1	0	3	0	8	6	
9	0	1	2	6	0	9	8	

DATA.

Cost of Planks 12ft. × 9″ × 3″..... 2s. 4d. per
Do. Iron per cwt..... 16s.
Do. Puddle putting in,..... 8d. per cubic yd.
Do. do. taking out,..... 9d. do.

(8th February.)

A new Drainage Instrument, combining the advantages of the Theodolite and Level; by GEORGE YEATES, ESQ., M.R.I.A., Member.

MR. YEATES exhibited an instrument on the principle of the spirit level, by which levelling operations were performed in the ordinary manner, and having a graduated base plate similar to the theodolite, by means of which, horizontal angles could be observed. This plate could be disengaged and fixed in a vertical position, so as to enable the observer to read angles of elevation and depression. By these arrangements, an useful combination of the theodolite and spirit level was obtained, which would be found of much utility in the execution of works connected with drainage, also in surveying and other operations.

The advantages which this instrument possessed in addition to its combined properties, consisted in simplicity in construction, and the consequent mitigated liability to derangement, economy in cost, facility in taking observations, and its portability.

An account of the proposed Balance Gates and Regulating Weirs for Lough Erne; by W. T. MULVANY, ESQ., M.R.I.A., Vice-President.

MR. MULVANY described the arrangement proposed to be adopted in the construction of the regulating weirs for the navigation in the Lough Erne district.

This project, which combined navigation and arterial drainage, was one of vast importance to the district, and the works were being executed under the directions of the Commissioners of Public Works.

In consequence of the great quantity of water received in the extensive catchment basin, it became a matter of grave consideration to effect its discharge, in such a manner, as to cause the least possible impediment to the navigation, and at the same time, to provide for the efficient drainage of the land.

The proposed regulating weirs, it was conceived, would possess these combined advantages, and the models which were exhibited, clearly explained their construction.

An account of the mode adopted for raising the Roof of the Presence Chamber, Dublin Castle; by JACOB OWEN, ESQ., M.R.I.A., Member.

FOR the purpose of affording additional means of ventilation, and for the improvement of the architectural character of the Presence Chamber at Dublin Castle, it was determined to give increased elevation to the room, and as the pilasters and surmounting entablature, which was continued round the walls, formed prominent features worthy of being preserved, it was deemed expedient that the design for the new ceiling, should be made subservient to this end.

The Chamber is thirty-nine and a half feet, by thirty-six and a half feet, having a framed queen post roof, the outside of the rafters being sheeted with deal, upon which the slates were laid. Upon a careful examination, the

timbers having been found to be perfectly sound, Mr. Owen conceived the most expeditious and economical mode of proceeding was to raise the roof, as it then was, to the required height, instead of adopting the ordinary plan of taking asunder and refixing all the timbers ; and this arrangement presented the further advantage of affording, without additional expense, a means of protection to the chamber, against the effects of the weather during the operation. The slates having been discovered to be perfectly decayed and unsound, were removed, as it was deemed inexpedient to increase the weight to be overcome by this useless addition.

The flat compartment of the ceiling was first cut away, in the clear of the cornice, so as to preserve the entablature intact, and the trussing of the cornice disconnected with the ceiling joists. The buildings on either side being higher than the chamber, the ends of the tie beams of the trusses had been let into the walls, and gutters formed longitudinally ; it therefore became necessary to have the walls chased to the heights required to be gained.

Well braced stages were then erected within the chamber, along the walls, and longitudinal pieces were placed under and in connexion with the trusses of the roof, resting upon the heads of the screw jacks, one at either end of each truss. When all the staying had been properly braced, the screw jacks were worked together, and the entire roof was gradually and steadily elevated ; and according as the weight was raised to the extent of the screw jacks, the apertures which had been chased in the walls were built up with bricks and cement.

In this manner the operation was continued until the required object was effected, with the most perfect success, and at a comparatively trifling cost.

When the roof was raised and secured, the ceiling was bracketted out in conformity with the design, and coves were constructed therefrom to the top of the cornice, so as to form the connexion with the entablature.

(14th March.)

On the Drainage of the Mantua Turloughs in the County of Roscommon, and the formation, for that purpose, of a Deep Cut through Kinclare Bog; *by* THOMAS J. MULVANY, ESQ., Member.

THE drainage, with a view to reclamation, of the deep red bogs which cover so large a portion of the surface of the country in many districts of Ireland, is a subject which has naturally attracted a great deal of public attention for many years. The best and most economical mode of effecting this object, the extent to which it is desirable that the operation of drainage should be carried, and the amount of advantage to be derived from the reclamation of the bogs when drained, are matters which have given rise to much discussion and scientific investigation. A very minute enquiry was made into those subjects by the Commissioners who were appointed for the purpose, in the year 1810, and the result was a strong conviction of the practicability and great advantage of bog drainage: yet since that period, scarcely any attempt has been made to test the accuracy of the conclusions then arrived at, or to turn to a good account any of those immense tracts which are still perfectly useless except in the eyes of the sportsman. Any works of bog improvement that have been undertaken,

have been generally (and perhaps judiciously, in the first instance, as a matter of profitable speculation,) confined to shallow bogs which did not require much more than ordinary surface drainage. I am not aware of a single case in which the perfect drainage of a deep red bog (by which I mean the drainage of the whole mass of peat, down to the substratum on which it rests,) has been effected or attempted.

The construction of works passing over or through these tracts of wet bogs, furnished also a subject of important consideration to the engineers, particularly to those engaged in Ireland, where such tracts are so frequently to be encountered in carrying out any extensive projects, either for the purpose of general public communication, or of local improvement.

The making of roads through bog is a work of every day occurrence, and the principles to be followed in their construction and maintenance appear to be generally admitted and understood, although very seldom adhered to in practice as strictly as they should be. The formation of cuts on a large scale through red bog, either for the purpose of navigation or drainage, is of less frequent occurrence; and previous to the great experiments of that nature tried in the construction of the Grand and Royal Canals, very little was known about such works, and very erroneous ideas were entertained on the subject, even by the most eminent engineers of the day. The results of the experience afforded by these important works, together with an amount of very valuable information on the subject of bog works generally, have been given to the public in the interesting paper communicated to this Institution by the Messrs. Mullins, in the year 1846. That paper contains, I believe, the best practical infor-

mation which has been published relative to the peculiar class of work to which I now allude, and it cannot fail to be of great use and assistance to persons engaged in any similar undertakings.

In my own case, I am bound to acknowledge the advantages I derive from the Messrs. Mullins' communication, which was published* in the early part of the year 1846. In the course of the same year, I was called upon to examine and report on the proposed drainage of the Mantua Turloughs, in the County Roscommon ; and amongst the works designed for that purpose, the principal one was the formation of a cut, varying from twenty to thirty feet in depth, and nearly a mile in length, through one of the most wet bogs in the County Roscommon. In conjunction with the formation of this deep cut, it was also proposed to effect the complete drainage of the bog on both sides of the cut, to the extent of upwards of three hundred acres. This work is now far advanced towards completion, and I have prepared the accompanying plans and sections to illustrate the objects and design of the undertaking, and to exhibit the progress and results of the operations on the bog.

I trust that the degree of interest to which I have alluded, as attached to works of this description, may be considered a sufficient apology for my taking up the time of the Institution with a few remarks on the peculiar formation of the district in which the bog and turloughs are situate, and a short account of the progress of the operations up to the present time.

The bog cut which I am about to describe, constitutes a part of the works of the drainage district of Lough Gara and Mantua, which are being carried on by the Com-

* Vide Transactions of the Institution of Civil Engineers of Ireland, Vol. II.

missioners of Public Works, under the provisions of the General Drainage Acts. The immediate object of the cut, as I have already mentioned, is to relieve from inundation the Turloughs of Mantua, one of the largest and most valuable groups of turloughs in the County Roscommon, comprising about seven hundred acres of fine land, which is so circumstanced as to be liable, at certain periods, to be covered with water to a depth of from eight to ten feet, over the greater portion of its surface, and in some places to so great a depth as sixteen or eighteen feet. These turloughs are situate about three miles west of Elphin, and at the rere of Mantua demesne, from which they take their name.

The cavernous limestone formation of a considerable portion of the County Roscommon, gives origin to a number of turloughs, more or less similar in their circumstances to those of Mantua. In different parts of that county, there are extensive tracts of high table land, the surface of which is undulating, and covered with a shallow porous soil, lying on the limestone rock: these constitute the richest grazing lands in the county; such as the celebrated plains of Boyle, the Hill of Rathcroghan, &c. There are no streams or leading drains to be found in those districts. The rain water which falls on them is absorbed at once, through the porous soil and the fissures of the rock, or sinks into the "swallow holes," which are frequently to be met with on the surface, and appears to be received into some extensive cavities within the mass of rock, whence it is discharged again into springs round the verge of the table land. The streams from those springs frequently flow into some low basin, from which there is no overground course, by which the water can pass off, but in the bottom of which, there may

be one or more subterraneous passages, or "swallow holes," as they are generally called, which, during the summer, afford sufficient means of discharge, not only for the water supplied by the springs, but also for the quantity of rain that usually falls within the area of the basin itself, at that period of the year. When, however, there is any continuance of wet weather, those passages are generally found insufficient to carry off the increased supply from the springs, and the drainage from the immediate rain basin; and the water consequently rises, and covers the lower portion of the lands, and continues to rise until it finds vent at the lowest point of the verge of the turloughs, or until the discharge through the swallow holes is sufficiently accelerated by the head of water over them.

Turloughs which owe their origin only to those causes, constitute the simplest cases of the sort to deal with. In fixing on the means to be adopted for their drainage, one of two courses must be followed, either to cut off the principal supply from the swallow holes, which may be accomplished by altering the course of the stream, (if practicable) before it enters the turlough, or carrying it in a contour course, round the deep part of the turlough, and across the lowest point of the ridge which bounds it; or else to make a cut through that part of the ridge, to such a depth as to secure the perfect drainage of the turlough at all times. A deep cut of this description is always preferable to a contour course, if practicable, at a moderate cost, as being more certain in its effect, and free from risk of accident, or expense in its maintenance.

There are some turloughs, however, which are of a more complicated nature than those I have described, being connected with other turloughs by means of their

subterraneous passages, which therefore, though acting as swallow holes at some periods, carrying off the water poured into them, are found at other times, when their services as conduits for discharges would be most required, to act in the opposite way, as fountains whence the water from other places rises, and aids the inundation of their own basin. It is therefore essential, when devising means for the drainage of such turloughs, to investigate closely the natural causes which affect them. The works necessary for their relief may be situate at a considerable distance from, and apparently quite unconnected with, the turloughs themselves, the object being, in such cases, to cut off the supply, not only from the basin of the turlough, but also from the swallow holes, in whatever direction they may be situate, which communicate under ground with the passages from the turlough.

The turloughs of Mantua are situate at the northern verge of the most remarkable of the tracts of high table land to which I have alluded. It extends for a length of upwards of ten miles, from near Elphin to Ballintobber, and for an average breadth of four or five miles, between Tulsk and Ballinagar. Its elevation varies from three hundred and fifty to five hundred feet above the level of the sea. As in this large tract of between forty and fifty square miles, there are no rivers or streams to carry off the drainage water, the great quantity of water which falls on this surface in time of rain, must be received directly into the fissures of the rock which forms the substratum, and collected in caverns, (of the existence of which there are indications on the surface in many places,) there to form the source of supply to the springs which abound along the verge of the district in all directions.

These springs are found in the greatest number, and with the most copious discharge to the west of Elphin, between that town and the turloughs of Mantua. Some of them flow north and south of Elphin into the chain of rocks and rivers which lie between it and the Shannon; others rise westward of the summit, between the town and the turloughs, and flow into the latter. A number of these springs which rise in the eastern part of the basin of the turloughs, form the source of a considerable stream, which works a small corn mill in the townland of Ballyroddy, and flows into the lower turlough, where it disappears in one of the large swallow holes, a number of which are scattered over its surface, as shown on the Map, (see plate III.)

The turloughs are divided into three portions by ridges of comparatively high land which separate their waters, except in a state of high flood. The lower or eastern turlough is the largest and deepest; the middle turlough is the next in point of extent and depth, and the southern or Kinclare turlough is the smallest, and is connected with the middle one by means of a small artificial cut. When the flood attains its full height, it stands at the same level in all, and covers the greater portion of the ridge between the middle and lower turlough, forming one extensive lake, the general depth of which varies from ten to eighteen feet. The quantity of land covered in these turloughs at this state of the flood, is nearly seven hundred statute acres, the greater portion of which is of a very valuable description. The chief swallow holes are situate in the lower turlough, and it is generally believed that the water carried off by them is discharged at a place about five miles to the westward, called Poulnamaghul. Near this place, there are several large

springs or fountains, which commence discharging as soon as the turloughs at Mantua become filled, and continue flowing until the water subsides altogether in the turloughs, when the fountains dry up. While they are discharging, the stream from them is considerable, and is made use of to work a corn mill.

It is stated, that in order to ascertain whether this was really the point of discharge for the turlough waters, the experiment has been tried of putting large quantities of chaff into the swallow holes while they were acting, and then observing the discharge from Poulnamaghul, where it is asserted that the chaff was seen to come up.

After the turloughs become once filled with water, the subterraneous passages require a long time to carry it all off, even under the most favorable circumstances as to weather; and when the basin is nearly emptied, one or two days of heavy rain would be sufficient to raise the water to a high level again. It thus happens that the low lands are generally covered for eight or nine months in each year; and on one occasion, in the year 1811, the water remained in the turloughs for the whole season. This fact is recorded by Mr. Longfield, in his report on the bogs of Lough Gara district, published in the third report of the Commissioners. Speaking of the turloughs, and the swallow holes to which I have alluded, he says: "the last year's experience sufficiently proves how little those ventages are to be depended on, for in the month of August, 1811, the whole of these three hundred and eighty acres (Irish measure) of turloughs, (which, if kept dry, would be worth fifty shillings per acre,) was completely covered with water, which compels the inhabitants to resort to boats in going from one part of their dry land to another; and it was the general opinion of the

country, that the swallow holes were so completely choaked, as never to admit a free passage for the waters to run off again. This assertion, considering the two or three streams constantly running into the turlough, (one of which comes from the tail race of Balroddy mill,) to me appears probable, and induces me to think other ventages beside the gully holes are actually necessary."

The immediate rain basin of the turloughs, or that which—judging merely from the external formation of the country—would be considered such, is about four thousand two hundred acres in area, its summit line, which is represented on the map, runs along a ridge of high land, varying from sixty to one hundred feet above the level of the bottom of the basin, except on the western side, where it crosses the bog of Kinclare. The summit of this bog was originally about twenty-five feet above the bottom of the middle turlough, a lake called Lough Bally, communicating with the Breedogue river, which flows into Lough Gara. This was evidently the only line in which it was practicable to make a deep cut to drain the turloughs. Mr. Longfield, in arranging his plans for the drainage of the bog, proposed also to accomplish the relief of the turloughs from inundation, by making his main drain through the centre of the bog twenty feet deep at the summit. This depth was, however, fixed upon, evidently under the erroneous impression, that the general level of the lands in the turloughs, was only from three to six feet under the level of the high floods, while in reality the bottom of the middle turlough was fully ten feet below the level; and the bottom of the eastern turlough seven or eight feet lower still.

The cut which is now being made, will be thirty feet

below the original surface of the bog at its summit, so as to insure the complete drainage of the middle and southern turloughs by means of it. It was not considered necessary to make the cut as deep as the lowest part of the eastern turlough, because it is proposed to take up the streams which flow into it, at such a level as will admit of their being carried in a contour course round the very deep part, and through the ridge which separates the eastern and middle turloughs, into the new cut at its intended level. Any rain that falls immediately on the low part of the eastern turlough will be easily carried off by the swallow holes.

The section through the line of the new cut, shows that the bog of Kinclare rests in a cup of hard limestone, gravel and clay, the centre of which is twelve feet lower than the ridge between it and Lough Bally, and about sixteen feet lower than the bottom of the middle turlough. This fact naturally leads to the conclusion, that at some remote period, previous to the growth of the bog, there must have been an open communication between the turloughs and Lough Bally; and that the cup, in which the bog now rests, was then the bed of a lake. This conjecture is borne out by the fact, that we find the portion of this cup which is below the level of the ridge, between it and Lough Bally, filled with a deposit of fine marl.

The causes which may have led to the growth of the bog, and the probable period at which the change may have taken place, are subjects worthy of the attention of the geologist, and might probably afford a test of some of the theories which have been advanced relative to the origin of the bogs. I think, however, there can be little doubt that a change, such as I allude to, must have taken place in this instance at some period.

Before the works were commenced on Kinclare bog, it was one of the wettest in the country; even in the driest season it was impossible to walk across it without sinking to the ancles at each step, and it was necessary to be very cautious to avoid the portions which were not covered with a tolerably firm sod or scraw, and which, consequently, could not support the weight of a man.

The wettest portion of the bog was, as in all such cases, the highest part near the centre, its greatest height being, in fact, the consequence of its greater wetness, and remoteness from any means of drainage.

About midway, between the summit and the verge of the bog, towards Lough Bally, there was a spring, or rather a number of deep holes, in the bog, known by the name of Pulladhu, from which there was a constant discharge of water, mixed with fine particles of peat, and which flowed in a crooked stream through the bog, down to Lough Bally. This spring was situate nearly over the deepest part of the hollow in which the bog rests, and appears to have been supplied by the water retained within the cup beneath the bog, and acted upon by the superincumbent mass of peat and water. The discharge from this spring was much greater in wet than in dry weather; but it was never, I believe, altogether dried up.

The line fixed on for the new cut through the bog, follows the general direction of the stream from Pulladhu to Lough Bally, but avoids its crooked course, being a perfectly straight line from the commencement of the bog on the side of Lough Bally, up to the summit, from which point it curves slowly into the turlough. The length of the line from Lough Bally to the small pool called Carrigeen Lough, in the middle turlough, is very nearly two miles. About three quarters of a mile in

length, on the side next Lough Bally, and a quarter of a mile next the turlough, runs in eight to ten feet of cutting, through firm peat, with a substratum of limestone, gravel and clay. The centre portion, for nearly a mile in length, runs through the high wet bog, in twenty to thirty feet of cutting, below the original surface. The bottom was proposed to be ten feet wide when completed, and to have a gradient of seven feet in the mile, from Lough Bally up to the wet bog, and three feet in the mile from that point up to the turlough. This intended line of bottom is shown on the section, (see plate IV.) by a firm line. Further consideration has shown it to be desirable to carry up a deeper narrow cut, for the purpose of tapping, as much as practicable, the basin or cup in which the bog rests, and thereby insuring the complete drainage and consolidation of the whole mass, and preventing a tendency to fill up the bottom of the deep cut; the proposed additional sinking for this purpose is shown on the longitudinal and transverse sections, by dotted lines. The sides of the cut are formed with slopes of six inches to the foot, in the consolidated bog, and one to one in the clay and gravel.

The centre line of the proposed cut was laid out, and lockspitted across the bog, on the 9th September, 1846. The operation of forming surface drains all over the portion of the bog proposed to be drained, was then commenced. A drain was first formed in the line of the centre of the proposed deep cut, (plate V.) and two others parallel to it, and twenty feet distant on each side. Similar parallel drains were also sunk, at distances of ten statute perches asunder, on each side of the cut, to the extent of the bog proposed to be drained, and cross drains, at the same distance apart, leading into the

centre cut, to which they were inclined, at such an angle as best suited the natural inclination of the surface of the bog. The area of the bog was thus cut up into portions of about one hundred square perches. The surface drains were made three feet wide at top, eighteen inches at bottom, and three feet deep, or as near to those dimensions as the circumstances of the case would admit of. Near the centre of the bog, where it was wettest, it was quite impossible at first to open a drain to the dimensions I have described, as a portion of it would no sooner be cut, than it would be nearly filled in again. The drains in this portion of the bog could therefore be only opened to very small dimensions at first, and then constantly worked on, and gradually enlarged, as the surface became consolidated. Over the general surface of the bog, exclusive of this very wet portion, the drains were opened to the full dimensions without difficulty; but they gradually closed into a breadth of about eighteen inches at top, except near the verges, where the peat was tolerably firm, and where the drains consequently retained their form without any further working.

When all these surface drains had been opened, the three drains on the line of the proposed cut were enlarged to a breadth of six feet at top, two feet at bottom, and four feet deep; *every second* parallel and cross drain on each side of the cut was then enlarged to the same dimensions, care being taken to keep the centre drains constantly cleared, and in the enlargement of the cross drains, to work from the centre towards the bog; thus leading all the drainage water to the centre drains, where it was kept constantly flowing in a very considerable quantity. The centre and two side drains, and the portions of the cross drains leading immediately into them,

were constantly worked on, and deepened according as the gradual consolidation of the surface would permit, so as to secure the greatest possible amount of subsidence in the line of the main cut. When it was required to deepen the centre drains, the drainage water was turned down the side drains; the centre one was then cleared and deepened, the water turned into it, and the two side drains sunk to the same depth. The spoil from these three drains was placed on the bank between them, and small cross cuts were made from one side drain to the other, at distances of five perches, along the length of the proposed cut, in order to promote the consolidation of the intermediate banks of peat.

The drains I have now described, were all made in the months of September, October, and November 1846. The surface of the bog was then allowed to drain during the winter, without any further enlargement of the drains, but merely keeping them cleared, so as to ensure their efficient action. Small cuts were also made for any swampy places in the surface of the bog to the nearest drain, so as to prevent, as much as possible, any water lying on the surface. The men were employed, in the mean time, in excavating the solid peat and gravel in the line of cut, between Lough Bally and the wet portion of the bog, and also in the solid portion of the cut near the turlough. When the portions of peat between the centre and two side drains were sufficiently consolidated, they were excavated to the level of the bottom of the centre drain, and wheeled into spoil about midway betwen the side and the parallel ten perch drains. The centre drain was then sunk as deep as the state of the material would admit of, and kept constantly cleared, until the peat was sufficiently consolidated to

admit of another lift being taken off when the operation was repeated.

No excavation could be done at the summit of the bog, or within some distance of it on each side, for some months, and when commenced there, the operation had to be carried on much more gradually, than at the other portions. The sides of the cut in this wet portion of the bog, closed in, very much as the excavation was proceeded with, so that the top breadth, between the side drains, which was laid out at forty feet, closed to half that breadth in some instances. The spoil was spread in a thin layer over the surface, between the side drains and the first ten perch drain, but nearer to the latter, so as to press as evenly as possible on the soft part of the bog. This spoil, as might be expected, reduced very much in bulk as the water drained out of it, and there is now a very small show of spoil for the large amount of excavation removed, as measured in the cutting.

Early in April, 1847, we commenced enlarging the parallel drains, forty perches asunder; and the cross drains at some distances apart, to act as permanent main drains. The dimensions at first intended for those drains were the same as what were proposed by Mr. Longfield in the "bog reports" for his main drains, namely, six feet deep, nine feet wide at top, and three feet at bottom. Experience showed, however, that it was not only unnecessary, but highly injurious to make the drains so wide, because the wider the bottom is left, the greater will be the tendency in wet bog, for the soft material to rise up in the drain, being pressed on by the weight of the bank on each side, and left free to move in the centre. On the other hand, if the bottom be narrowed nearly to a point, and the sides left as nearly

perpendicular as may be consistent with security, against their closing in too much, there will be little tendency to rise in the bottom ; and besides, whatever quantity of water may be discharged through the drain, being confined to a narrow straight course, will have a very beneficial effect in keeping the drain clear. It was therefore found better to make those drains only from six to seven feet wide at top and not more than six inches at bottom, and from six to seven feet deep.

It will be observed that those main drains divided the bog into parallelograms of about ten acres in extent, which were subdivided by the minor drains into portions of two and a half acres, and still further divided by the surface drains into lots of one hundred square perches. These drains are all represented on the map—the surface drains by faint black lines, the minor drains by strong lines, and the main drains by double lines.

During the summer of last year, the excavation in the line of the main cut was proceeded with rapidly, all the principal drains being kept well cleared at the same time ; at the close of September, all the excavation that it was considered advisable to attempt at the time had been nearly removed. The men were afterwards chiefly employed, until near the close of the year, at the formation of the cut between the middle and southern turloughs.

Since the commencement of the works, the surface of the bog had been gradually subsiding to a considerable degree, particularly in the line of the main cut. At the close of the year 1846, it had sunk three feet ten inches at the summit ; and in September, 1847, one year after the commencement of operations, it had subsided ten feet six inches.

According as the main cut was deepened, the discharge

of water from Pulladhu became less, and ceased altogether when the new cut had been sunk to the gravel ridge, which forms the lower boundary of the cup beneath the bog. The holes through which the water used to spring up, are very deep, and have now the appearance of deep wells, the water having sunk to a considerable depth below the surface. At the same time that the discharge from Pulladhu decreased, the water began, as had been anticipated, to boil up in several places along the bottom of the main cut, but not in any very large quantities.

These facts appear to warrant the opinion which has been expressed, that the discharge from Pulladhu was occasioned by the water collected in the cup of the gravel beneath the bog, and not by any spring through the substratum itself, supplied from any remote place.

Early in December, the flood began to rise in the turloughs; and as the bottom of the cut, even at the summit of the bog, was now two or three feet below the usual level of the high floods in the turloughs, it was found necessary to make a small dam across the cut, a little on the turlough side of the summit. The floods rose to their full height on the 15th of December, and burst the dams on that day, when the water from the turloughs for the first time flowed through the new cut to Lough Bally. A new dam, formed of piles and planks, with a lifting sluice in the centre, was then put in, by means of which it was practicable to command the water in the turloughs, allowing it to flow through the cut, or keeping it pounded up, as was deemed desirable. By this plan, means were afforded to float off a good deal of sludge and loose particles of peat which have been deposited in Lough Bally, and in the lower portion of

the cut near that lake. When the water in the turloughs had lowered some feet in the early part of last month, the dams and sluice were removed from the summit, and placed in their present position (which is shown on the section) at the edge of the turloughs, and on the solid gravel foundation.

The present state of the cut, and the result of the drainage on the bog, up to the present time, is shown on the longitudinal and cross sections. It will be seen that the surface on the summit of the bog, and for a considerable distance towards Lough Bally, has sunk or subsided fully fourteen to sixteen feet. The bed of the cut, for the greater portion of its length through the bog, is brought within three or four feet of the intended level, and at the highest point, it is within nine feet of the required depth. It is not proposed to do much to the main cut until the dry season shall have set in. It is expected that Lough Bally, which is a shallow lake, will be completely drained in about three months hence, on the completion of some works now in progress on the Breedoge River. There will then be no difficulty in carrying up the proposed deep and narrow tap in the bottom of the main cut, as indicated by the dotted lines on the sections, so as to tap the bottom of the bog; after which it is anticipated that the cut into the turlough can be finished with ease in the course of the summer. The cut into Kinclare turlough is now so far advanced, that it can be finished in a week or fortnight after the flood subsides. There will then remain nothing to be done to complete the drainage of the turloughs, except the formation of the cut through the ridge which separates the middle and lower turloughs, and running the contour drain to convey the

Bally-roddy stream into the main cut. This can also be done during the summer months, so that it may be expected that after the present flood shall have subsided, the lands in the turloughs will never again be subjected to a similar inundation.

The change in the appearance of the bog since the commencement of our operations is very remarkable; the new cut lying in a small straight valley through the centre of the bog, originally the highest part, and affording to a person standing between the bog and Lough Bally, a prospect of portions of the country in the direction of Elphin, which were formerly shut out of view from that point by the summit of the bog.

The total length of surface drains opened in the first instance, was about 7400 Irish perches; of these, about 3900 perches were afterwards enlarged to the size of minor drains, and of the latter, about fourteen hundred perches were further enlarged to serve as main drains. From the line of main cut, between Lough Bally and Carrigeen Lough, there have been removed about 112,300 cubic yards of peat, and 5437 cubic yards of gravel and clay. All the work, with the exception of the constant clearing up of the drains, has been executed by task, the labourers being divided into gangs of ten or twelve men, to each of which gangs a certain amount of work was let from time to time, at a fixed price. The prices paid for the drains were 9d. per Irish perch, for opening them to the first dimensions; 1s. 2d. per perch for enlarging them to the size of minor drains, and 1s. per perch for enlarging the minor drains to the size of the main ones. The first mentioned price, 9d. per perch, for the surface drains, is perhaps rather high. The work was, however, done under some

disadvantages, in consequence of the very wet state of the bog, and the lateness of the season when it was commenced. Besides, the labourers were almost starving at the time, provisions being very dear, and it was also necessary to encourage them to adopt the system of the task work, to which they were at first averse. They worked well, after a while, and were able to earn from eighteen to twenty pence a day at the price mentioned. Under ordinary circumstances, drains, such as now spoken of, should not cost more than 7d. to 8d. per Irish perch, for opening in the first instance.

The peat excavation was paid for at prices varying from 1¼d. to 2½d. per cubic yard, according to the degree of firmness, the depth of the cutting, and the length of wheeling. The average price for the whole quantity removed, is 2d. per yard. The prices for the gravel and clay varied from 3d. to 6d. per cubic yard, and averaged 4½d. The total amount expended on the work up to the present time is £2075., which expenditure may be classified under the following heads:—

	Irish Perches			£	s.	d.	£.	s.	d.
Opening Surface Drains,	7400	@	9d. ..	277	10	0			
Enlarging Minor Drains,	3900	@	1s. 2d. ..	227	10	0			
Enlarging Main Drains,	1400	@	1s. ..	70	0	0			
Total for opening drains,....				£575	0	0	575	0	0
Occasionally cleaning and deepening all drains over the bog, and in the centre of the deep cut,.....							320	0	0
Excavation in Peat, 112,300 cubic yds., average price of 2d.							935	16	0
Do. Clay and Gravel, 5437 cubic yds. do. of 4½d.							101	18	0
Unwatering lower portion of cut near Lough Bally,.....							5	6	0
							£1938	0	0
Superintendance and incidental expenses,.....							137	0	0
Total,.....							2075	0	0

The portion of this expense which is chargeable to the drainage of the bog, may be taken at about £600. or £2. per acre, the remainder of the sum already expended, £1475., does not amount to much more than £2. per acre on the lands to be relieved from inundation in the turloughs, and the total cost of draining those lands will not exceed three pound per acre—a sum, fully two-thirds of which was liable to be lost in any one year, by the continuance of the floods during the whole season, as was the case in 1811.

The cost of both the bog drainage and the main cut, would undoubtedly have been something less, if the operation could have been extended over a longer space of time, say three or four years instead of two. But there were several reasons for executing the works expeditiously in this case. It would not be convenient, or economical in point of management, to keep it in hands for one or two years after the works in the other portions of the district should have been completed; besides, it was a matter almost of necessity, to give as much employment as possible in the neighbourhood of those works, during two seasons of great distress. But the principal reason, which of itself would have been sufficient to determine the speedy completion of the cut, is the fact, that the estimated annual loss sustained by the ordinary flooding of seven hundred acres of land in the turloughs, is upwards of £500.; and this estimate has reference merely to the fair increase in the letting value of the land, and not to the positive value of the crops which might be obtained off it, if free from flood; so that there is a manifest advantage in having them relieved one year earlier, even though it should cost three or four hundred pounds more than a slower process.

As a general principle, however, in the mere drainage of those wet red bogs, for the purposes of reclamation, I should certainly recommend a slow process, as the cheapest and most satisfactory.

By such a mode of proceeding, in almost all cases where there is a sufficient fall to admit of the bottom of the bog being tapped, I am satisfied that in the course of three or four years, all the superfluous water may be drained out of the bog, and the whole of the peaty mass be *retained* and consolidated, instead of being carried off to the main rivers or drains of the district, as it must be to some extent if the operation be hurried, and where it sometimes becomes a serious impediment to drainage, or to the navigation of the river in which it settles.

In the portion of the Lough Gara district below Lough Bally, there are immense tracts of red bog, through which the Breedoge River and its tributaries flow, and for the drainage of which, splendid opportunities will be afforded by the improvements now in progress in the district. The river in its improved state, will not only be sufficiently lowered to allow of the perfect drainage of those bogs,* but being navigable for boats of a large size, will afford the means of conveying gravel and other manures to the very verge of

* Since this paper was written, I have had some sections and borings taken to ascertain the level of the hard stratum in which these bogs rest. From an examination of those sections, I find that some portions of the cup in which the bogs rest, are greatly below the level to which the Breedoge River has been sunk, or to which it would be practicable to sink it. It will not, therefore, be possible to effect the complete drainage of the *whole* mass of those bogs in the manner above alluded to, but a large portion of them may be so drained, and the remaining portions, which are situate over the very deep parts of the cup, may be drained deeply enough, but not so *cheaply* or permanently, as if the under water could be got rid of.

the bogs on which they may be required to be used. At Bella Bridge, about a mile below Lough Bally, a new channel has been cut for the river, three quarters of a mile in length, twenty feet wide at bottom, and from ten to twelve feet in depth, nearly all through limestone gravel and clay, of the description most valuable for the reclamation of bogs. The large quantity of spoil from this cut is laid on each side near the verges, where it can at any time be easily loaded into boats, and conveyed up or down the river as it may be required. Through some of those bogs, there are also new roads partly formed, which were commenced for the employment of the poor last year, under the Labour Rate Act. There will thus be, not only great facilities, but great inducements to undertake the improvements of those bogs. As far as their drainage is concerned, I am satisfied that when the river running through them shall have been improved, the proprietors, by adopting a judicious system of gradual operation on the drains, employing their labourers at them during those periods of the year when there is little other work to be done, and when employment is so much needed, may effectually drain them in the course of four years at furthest, and at a cost not exceeding thirty shillings per statute acre.

The bogs would then be ready for the application of whatever system of reclamation might be considered the most efficient and economical, and there is every reason to believe, that if properly treated, they would afford an almost immediate return of the capital expended on them.

A description of Framed and Canvass Dams; by J. BEVAN, ESQ., Member.

MR. BEVAN exhibited a model of a single dam, which he had used in the execution of some drainage operations. This dam was composed of strong guide piles, driven at suitable distances, with framed horizontal spur pieces and struts on the inside, to support the pressure to which the dam should be subjected to from the outside. The sheeting planks were fitted in horizontally, between the guide piles, in a similar manner to that described in a former paper on the "caisson dams," and painted canvass was laid over the planking on the outside, the lower part of which, being loaded by a chain, or other weighty substitute, was caused to lie, for some feet, on the bed of the river in front of the dam, so as to form an apron. Upon this apron, and in front of it, some good puddling stuff was thrown, for the purpose of preventing the passage of the water underneath. This dam was found very effective in shallow water, being sufficiently staunch for the required purpose; and was economical in its application, as being easily constructed and removed, and all the parts being useful for other operations, also the absence of puddle, as used in coffer dams, was an important advantage in facilitating its removal.

An account of the Carrigaline Bridge over the River Lee, on the new Cork and Macroom Road; by JOHN BENSON, ESQ., Member.

THIS bridge consisted of three segmental arches of fifty feet span each. In the course of erection, the arches

fell; and upon Mr. Benson being appointed County Surveyor for the East Riding of Cork, it became his duty to give a design for the rebuilding and completing of the bridge, and also to carry his design into execution.

Mr. Benson exhibited a drawing of the bridge as built, also a model explanatory of the mode adopted in its execution, showing the construction and arrangement of the centres, the traverse frame, and the setting machine used for carrying on the operations.

The principal feature in the work was the economical construction of the centres, which were judiciously framed, so as to present the greatest strength consistent with the quantity of timber used therein.

[April 11th, 1848.]

Observations on the Sewerage and other sanitary improvements of Dublin; by BERNARD MULLINS, ESQ., Vice-President, and M. B. MULLINS, ESQ., A.M., Member.

THERE are few subjects of more deserved interest, and none involving more difficult questions of principle and detail, than that which we are about to treat of; and as it is daily becoming of more importance, and is peculiarly exposed—from the conflicting control of different public bodies—to the evil of good intentions, not often in the right direction, we propose to review the whole matter, going back to the period when considerations of this nature imperatively forced themselves on public attention.

In the Summer of 1832, when this city had been

visited by that alarming disease, the Asiatic Cholera, then pervading the greater part of Europe, a Board of Commissioners of Health was appointed by the Government, for the purpose of ascertaining the best means of arresting its progress, and alleviating its malignity. By the investigation then set on foot, it was found, as might be expected, that in localities where dense masses of the population congregated in narrow streets, lanes, courts, and alleys—the sewerage and supply of water wanting or insufficient—ventilation unattended to, and the atmosphere vitiated, the malady was greatly aggravated, and the mortality proportionably increased. Subsequent experience has only tended to confirm the truth of the then observed facts; and although there is reason to doubt the accuracy of the conclusion come to by the Metropolitan Sanitary Commissioners, namely, that Cholera is not contagious, yet sufficient evidence has been elicited by them to corroborate the fact observed in 1832—from whatever cause the disease may arise—that sickness and mortality from Diarrhœa, and from Typhus of precisely the same type as that which preceded the former visitation of Cholera, have been excessive amongst the population of the low, ill-drained, ill-cleansed, and over-crowded neighbourhoods that are marked as the Cholera tracts of 1832.

The question of the contagiousness of Cholera involves, independently of structural improvement, a serious consideration, as to the necessity of the isolation of the sick; and as a belief leading to so desirable a precaution, would be clearly productive of more benefit to the community, than acting on the opposite opinion, it will be desirable that all the sanitary measures and precautions, admitted to be necessary in guarding against

contagious diseases, be adopted leaving, the *vexata questio* to the medical profession, whose differences of opinion have, perhaps, arisen from the fact, that the exclusive theory of neither party adequately accounts for the various circumstances under which the disease arises; the truth probably being, that it is communicated as well by atmospheric causes, as from infected individuals, to those who are predisposed.

It being a well-ascertained fact, that the mortality of cities is nearly double that of the country, it cannot be doubted that the putrescent exhalations of animal and vegetable matter which abound in the former, are among the causes of the less duration of human life; and as the same causes are admitted to act alike injuriously on all the diseases to which crowded localities are subject, it will be well to draw attention to the following facts, taken from the report of a society of experienced physicians, at Birmingham, setting forth some of the principal sanitary conditions tending to exemption from febrile diseases.

Those physicians state, that fever and like ailments are little seen there, and that the great differences between Birmingham and other towns where fever prevails are—1st, that it is built on hilly ground, from which there is easy drainage; 2nd, that there is throughout the town abundance of water from excellent wells; 3rd, that the filth from drains is at once carried away, by the small and rapid streams which pass through and near the town; 4th, that none of the people live in cellars below the levels of the streets and drains—cellars always becoming, as seen in Manchester, receptacles and retainers of filth; 5th, that the houses of the greater part of the population are small distinct dwellings, one for each family,

placed, it is true, around courts not very open, but in contrast with the large houses of Edinburgh, because where there is clear responsibility as to who should keep the house clean, there is almost sure performance of the duties; and if by any accident foul air should be generated in a house, it cannot, as in a large house, spread to other families, for there is no communication for person or maleria, but through the open air.

Another striking instance is that furnished from Nottingham, where fever was met, not, as might be expected, only in the low ill-drained parts of the town, but remarkably also and obstinately, in one of the most elevated and airy streets; but on closer examination, it was found that the drain of the street was made quite level, or without a descent, and that consequently it did not empty itself, but allowed all its filth to ooze or soak into the adjoining soil; and in Derby, in a certain street of fifty-four similar houses, fever prevailed much in six houses near the middle, while it did not at all appear in the others. On examination, after a time it was discovered, that by accident the six houses had been left unconnected with the public drain.

The unpleasant effluvia arising from the Liffey at low water, being an old source of annoyance and apprehension to those living in the neighbourhood, as well as to passengers along the quays, could not fail to attract the earliest attention of the Commissioners of the Board of Health at the period referred to. They accordingly obtained the advice of several engineers, whose plans were subsequently submitted to us for our opinion as to the most eligible to be adopted; and we are thereby enabled to lay before the Institution those which appeared to us worthy of attention.

On reference to the map it will be seen, that the Liffey, running from west to east, bisects nearly equally the city for its entire length. The ground is, for some distance from the river, flat on either side, rising to the termini of the canals which encompass it. These canals enter the river at opposite sides; the one near the confluence of the river Dodder with the Liffey, the other a little higher up, east of the Custom House Docks. With the exception of a small section, of which Mountjoy Square is the summit, the whole of the drainage of the city falls into the Liffey. In dry weather there is very little land water in the river, and the ebb of neap tides is not sufficient to carry the fetid deposits of the sewers out to sea; so that an accumulation, in the intervals of spring tides, occurs, which being deposited on the banks exposed at low water, causes the nuisance complained of. It was observed, that between Whiteford and Richmond Bridges, the Liffey quay walls were founded at a level so low, that a slight obstruction, raised by part of the old foundation of the more eastward of those bridges, pent up a quantity of water sufficient to cover the bottom of the river for its entire breadth, which completely prevented the ascent of disagreeable smells from the part so covered; the effect thus produced, suggested to Mr. Griffith the idea of constructing a half-tide dam, a short distance west of Carlisle Bridge; this was objected to by the Ballast Board, who have the conservation of the river. He also gave a design for parallel sewers along the quays, on either side of the river, to intercept the street sewers. In this plan it was proposed that the parallel sewers, at their upstream heads or commencements, should be inserted into the Liffey quay walls, having their under lips laid at the level of low water, and their discharging ends termi-

nating in deep water, eastward of Carlisle Bridge. It was likewise suggested, that the tidal water should be so directed, as to keep those main sewers free from deposit; and that in situations where the intercepted sewers had tide sluices, similar contrivances should be fixed in corresponding sites in the parallel sewer walls. Amongst other schemes, it was proposed by Mr. Beresford Smith, one of the Board of Health, that the stream of the Liffey should be narrowed and straightened, by constructing flagged *water sheds* from the foot of the wall on each side of the river, to the margin of the contracted stream, into which the sewage was to be discharged, and carried to sea by the increased velocity of the narrowed channel. This project met the approbation of the Ballast Board, but was abandoned from its costliness, which was estimated by their engineer at £105,000.

It was also suggested at the time, by Mr. MacMahon, that parallel open sewers might be established, by constructing two walls or mounds in the bed of the river, equi-distant from the present quay walls. These mounds to penn in one-half or three-quarters neap tides, whichever on enquiry was found best suited to the objects in view; the spaces on either side between the mounds and the present quays, to act as cess pools. The penned tidal waters, renewed twice every twenty-four hours, would cover the mouths of the several sewers to a sufficient height to prevent the escape of noxious effluvia; and the cess pools could be completely scoured for their whole length, by spring tide water, retained by sluices and dams in the reaches of the river between Barrack Bridge and Island Bridge. Mr. MacMahon also suggested, that it would be more judicious to divide the penns into convenient lengths, by stop dams and side

sluices, so as to give facility for the excavation and removal of the contents in lighters, the manure so obtained, from its fertilizing quality, was stated as more than adequate to the repayment of the cost of construction and maintenance. A somewhat similar plan was recently adopted in the channel of the river Froam, by the Bristol Town Council, for the improvement of the sewerage of that city, devised by Mr. James Green, C.E., and carried into execution by him, as appears by the proceedings of the Institution of British Civil Engineers, and attended with complete success, accomplished at the very moderate expense, as the report states, of £4537. But in this city that plan could not be carried eastward of Carlisle Bridge, from the hindrances presented by the entrances of the Custom House Dock, George's Dock, and the Royal Canal Dock, on the north side, and the great fleet of coal vessels constantly occupying the south side of the river in front of the city quay.

It having been manifest, that whatever measure might be proposed for the improvement of the sewerage connected with the Liffey, should have the approval of the Ballast Office Corporation, as conservators of the navigation of the river and of the port of Dublin, and it having appeared to us, that Mr. Griffith's plan of parallel sewers, terminating eastward of Carlisle Bridge, was the best that had been offered to the consideration of the Board of Health, we suggested the following modification of it, in conformity with the views of the Ballast Board—namely, instead of discharging the entire sewage into one reach of the river, east of Carlisle Bridge, that it should be distributed partially in the intervals of the Bridges as follows:—

From Barrack-street Bridge, the most westward in the

city, to Queen's Bridge, there are on the north side twenty-four sewers entering the river, and on the south side, in the same limit, twenty-two; the contents of these we propose to discharge from the two parallel sewers, by one conduit on each side into mid-channel, the outlets to be some distance from each other.

From the Queen's Bridge to Whitworth Bridge, twenty-seven sewers enter the river on the north side, and twenty-six on the opposite side; these were to be combined in the manner before mentioned, and so of all the others. From Whitworth Bridge to Richmond Bridge, twenty-one sewers enter; from Richmond to Essex Bridge, thirty-one; from Essex Bridge, to Carlisle Bridge, thirty. Thus there are, in a distance of three hundred and thirty-two statute perches in length, one hundred and eighty-one vomitaries of fetid discharge. If these were intercepted by parallel sewers, and the contents directed into five conduits or pipes, on each side of the river, one in each of the spaces between the Bridges, and that these pipes, passing from the parallel sewers through the quay walls, were carried into the constant current of mid-channel, and flaped at their mouths by self-acting valves, little doubt can be entertained that such a measure would considerably palliate the existing evil; and it is probable that further benefit would be obtained by reducing the number of out-falls to three instead of five on each side within the limits before mentioned; and by penning the tidal water, by means of a lock above King's Bridge, an effective scour might be brought to act on the channel of the river, by opening the sluices of the lock-gates, when the tide had fallen within one third of its lowest ebb; but in order to carry out this plan, it would be necessary to

purchase the valuable mills at Island Bridge, and protection should be given to the foundations of the quay walls, which might be sapped by the current.

At the points where the parallel sewers were to commence upstream near the King's Bridge, we recommended that a communication with the Liffey should be made, either by sluices in the quay walls, or by overfalls at suitable depths, in order that the flood water might flow into them, and be retained by proper flushing gates, for the purpose of scouring out consecutively the deposits from the tributary sewers, through the outlets into the conduits before mentioned; thereby distributing, at intervals, their contents partially in the stream of the river, where its velocity was greatest. By this means all the lighter portions would be carried out to sea; whereas if discharged within one short reach at or near Carlisle Bridge, it would be so unpleasant, if not injurious, to the inhabitants of that locality, as to cause an opposition sufficient to defeat the carrying out of such a plan.

Having observed that the great number of coal ships constantly in the river, lying athwart, moored to the south quay wall, and deeply imbedded in black mud, retained vast quantities of rubbish and filth, which were constantly carried back into the upper reaches by the inflowing tide, and re-deposited in the eddies; and seeing that any extension of the lateral sewers, so as to discharge eastwards of the Custom House Docks, would only be a transfer of the evil lower down, and would have the additional ill effect of tending to silt up the entrances of the locks in the vicinity, or at least those of the Grand Canal Docks, on the south side, already injuriously affected in that way, by the confluence of the Dodder with

the Liffey, we proposed to the Board of Health, that the sewage of the city should be carried altogether, irrespective of the Liffey; and with that view, that the parallel sewers should be extended from the termini first proposed at Carlisle Bridge, to the strand near Irishtown, on the south side, and to the estuary of the Tolka, on the north side. The southern parallel sewer to be taken up at such a distance eastward of the confluence of the river Dodder with the Liffey, as would suit an extension of this sewer from the point of departure on the quay, passing under the first ascending level of the Grand Canal, in order to reach Irishtown Strand.* The north parallel sewer to be extended to the Tolka estuary, passing under the first ascending level of the Royal Canal, a short distant west of Sherriff's-street Bridge; reservoirs to be be made at the termini of those sewers, with contrivances for the retention of the solid portions of the sewage, which in fertilizing properties would hardly be inferior to any description of manure. Those depots might be placed in situations of convenient access, for the removal of their contents as occasion would require.

The plan of distributing the sewage into the centre of the river, by pipes on either side, is liable to the objection that it is only a palliative; and while it would save one organ of the body from offence, it might not give

* Since this proposition was made, a considerable portion of the strand east of Irishtown has been reclaimed, by the deposit of the material dredged out of the sailing channel of the estuary, consisting, in great part, of deposit from the sewers. An embankment is now formed of it, in the rere of the south wall, containing upwards of 350,000 cubical yards, part of which is cultivated, growing luxurious crops of corn and meadow. At the foot of this embankment, the sewer may debouche, by a trifling alteration in the original plan.

others an equal immunity; for it is by no means established that the most fetid particles are those most productive of disease; and as to the delivering of the putrescent matters, mixed with large quantities of water from various sources, into great cess lakes, while it removes the nuisance to what may be called a safe distance, it must be admitted that it would require some ingenuity of contrivance, to utilize, at a remunerating cost, the valuable portions so diluted, unless a ready market were created for the disposal of the manure in a liquid state, on the improved plan of such application to agricultural purposes.

The sewers of the city at the period referred to were ascertained to be very defective, both as to form and construction; the bottoms being flat, and the side walls upright; the dimensions seldom corresponding with the drainage required; large sewers being found in places where there was no necessity for them, and small ones where they must prove inadequate; in short, a general want of any uniform system of arrangement or level pervaded the whole.

At that period, Mountjoy Square was the only locality that had a sewer with an invert; but it was built unnecessarily large, six feet high, and three feet wide; its height having been given, not for required capacity of sewerage, but to admit men to enter for the removal of the deposit, in the absence of any mode of prevention or cleansing by other means.

This sewer being the first attempt at improvement on the old system of rectangular form, and having cost the large sum of £18. per lineal perch, did not apparently lead to any very decided taste for that description of innovation; and consequently the city is in much the

same condition as in the year 1832. The obvious advantage of the invert has not been adopted in any of the new main sewers, which are all flat bottomed, and they are uniformly of the same dimensions as the Mountjoy Square sewer, and for the same reason as above stated.

There are many important localities requiring large sewers, where the largest is but three feet high, and two feet wide; and there are other portions most in need, such as about the slaughter houses in the neighbourhood of Cole's Lane, where there are no sewers.

The house drains are also constructed on a defective principle, being one foot six inches square, and not nearly as efficient as tubular drains or pipes of nine or twelve inches in diameter, which would be cheaper and easier laid, with a better fall; and it not unfrequently happens, that the house is built without reference to the level of the main sewer; and the Paving Corporation are then called on to make the junction between the main and the house drain, which is found to be too low. The consequence of such a state of things needs no comment.

It is manifest that no partial plan of improvement is applicable; the whole must be systematized from the summit to the outfall; and for that purpose the levels of the main and branch sewers should be accurately ascertained, having reference to a fixed datum, and their levels delineated by contour lines on the ordnance map; noting particularly the various crossings and intersections of the branch sewers, with the main lines of drainage, in order to determine the capacities suitable to each particular locality; keeping in view the expediency of giving sufficient sectional area to such as shall be placed within the range of tide, whilst those on the highest levels may be proportionably less, as circumstances may suggest.

To ascertain the relative levels of the main and minor sewers, the streets must be opened where necessary; and registered bench marks permanently fixed, to which access can at all times be had, indicating their respective heights above datum; by this means the falls can be regulated, and the sizes of the sewers graduated according to their respective inclinations. There should also be a uniform system of levels and of interdependent sewers laid down, so as that a current of water running from those above, might traverse and cleanse as extensively as possible, before it reached the parallel main sewer in the valley line; care being taken that the inclinations be such as to produce a velocity, at which no deposit will take place.

The above preliminaries being arranged, the desired improvements might be gradually carried out, extending the expenditure over a certain number of years, so as not to bear too heavily on the citizens, and giving the benefit of the earliest attention to those localities most in need of improvement; but in the absence of the above indispensable data, it should be considered impracticable to proceed.

As to the form of sewers, that is the best which, combining stability with economy, discharges most rapidly, thereby preventing deposit; and these qualities are found in the opposite of the rectangular form in use, namely, the circle; and under circumstances where, with a limited flow of water, contraction of the stream produces depth and velocity, there can be no doubt that such a combination of curvelinear configuration as the oval, or egg-shape, presents, the small end, or segment arch, being turned downwards, is the most advisable; but where there is a great and constant flow of water, the adoption of the circular form may be advisable. We do

not approve of the semieliptical bottom of the oviform sewer, on account of its want of sufficient bearing, and that it requires more care, and causes more difficulty in the construction; but the same objection does not apply to the true elipse, which is a good form to adopt with a medium supply of water.

The size is also a consideration of great importance, as much error has prevailed, and expense uselessly incurred, by a supposed notion of the necessity of sewers of large dimensions, without reference to the quantity of drainage, which, with the fall, should be the guide to the capacity, bearing in mind, that the greater the capacity beyond proper limits, the less the force of the current will be, and consequently the greater the tendency to deposit; and even in main lines, where the greatest flow is to be expected, it is a matter of general observation, that the discharge at the mouths, under ordinary circumstances, is the smallest quantity of water that could be called a stream. We attach notions of superiority to large dimensions, and take utility for granted on the faith of our prepossessions.

It would be difficult, if not impracticable, in the absence of a proper survey, to lay down any fixed rule as to size, that would be applicable to the combination of a well systematized plan, having a circulating current pervading the whole.

When the falls of the main sewers shall be ascertained, and the falls of the branches, it will be easy to determine, according to the various circumstances, the relative proportions of the branch sewers to the main; and no general rule applicable to all places can be laid down, for the capacity of the main sewer must be greater or less, in proportion as its fall is greater or less, relatively to the

falls of the branches; or in other words, if the fall of the main be sluggish, and that of the collateral sewers be quick, the capacity of the former must be greater, than if the opposite condition to that stated of the relative levels existed.

Another point necessary to observe upon, is that the old method of joining sewers at right angles should be abandoned, and properly curved junctions adopted, the effect of which in preventing deposits from drop-pipes, or where branch sewers fall into the main from opposite directions, is obvious, by giving an onward motion, instead of producing eddies, by the counteracting forces of opposing currents.

There is no want of theoretical knowledge on the points of hydraulic science connected with the question of sewerage; and there are abundance of formulæ and tables that give us reasonably approximate knowledge of the required capacities of conduits under various conditions of areas of drainage; but there is an observable scarcity of sound practical knowledge, as applied to this subject, and a tendency to a reaction, from the large, expensive and ill-formed sewers, to the opposite extreme, in giving minimum size and section of work; for it should be borne in mind, that it will be difficult, under every circumstance, to bring such a scouring power to act as will dislodge indurated deposits, which must sometimes take place; and we should not adopt a system so rigid, as to exclude, under unfavourable conditions, access to the sewer without breaking it up. We do not, however, by any means wish to be understood as negativing the mode of cleansing by currents, if an adequate supply of water be effectively applied, in a sewer of proper form and inclination, and of stable construction.

The connexion of the street gullies with the sewers, in order to prevent effluvia rising into the atmosphere, is deserving of much attention. A remedy for the evil as it now exists, can be attained by a proper system of tubular gully drains, with an efficient grate and trap at top, and an air tight valve at its connexion with the sewer. By these means, matters likely to stop the drain will be retained at top, and the miasma will be prevented rising into the street; and this is certainly a more simple, though not apparently as scientific a mode as that devised for carrying off the gaseous emanations, as adopted for the consumption of foul air in coal mines, which we presume first gave rise to its proposed application to the purpose under consideration.

The ventilation of sewers is an idea of modern times. The first notice that we have seen of it is in a report by a commission, appointed in Paris, in 1829.* The mode adopted, consisted of an iron chimney, placed over the gully hole, and a fire, suspended in a grate over the sewer kept burning, while men were working below a draught was thus produced, and the foul air carried off. This was only a temporary expedient, to enable the men to proceed with safety where inflammable gases might have existed; but the mode of ventilation lately proposed, consists in placing over the sewers, a number of separate downcast and upcast shafts, of a certain height above the surface, with furnaces in the latter; the foul air of the drain will thus pass through the fire, and in supporting combustion, its noxious quality will be destroyed, while the cold air, rushing to supply the place of the ascended heated air, would be carried through the downcast shafts, and thus keep up the ventilation. Other methods, differ-

* Annals d' Hygiene Publique, vol. II.

ing only in detail, have been proposed, but we look upon them merely as the fanciful devices of ingenious men, and if at all applicable, not as adjuncts to a proper system of sewerage, which should provide for carrying off the noxious matter now forming exhaling deposits; and the proposed system of cleansing by constant currents of water, and by occasional flushing, would not only check decomposition, but would necessarily be attended with currents of air, producing the desired ends by one operation.

Another refinement of another science brought to bear on the question before us, has been introduced with some favour to public notice, under the designation of *deodorization;* and the chemical substances recommended for that purpose, have been called disinfectants, on the presumption that the supposed disease-producing portions of the gaseous emanations of putrescent matter, are also those which have the strongest and most disagreeable smell—a fact by no means proved; but in any case, the necessity of neutralizing the odours of cess pools and of other depositories, can only arise, as in the ventilation of sewers by furnaces, in a bad system; and therefore our efforts should be directed to obtain within the limits of expenditure, commensurate with the benefit conferred, substantial improvements, by the abatement of admitted nuisances, such as those undoubted laboratories of noxious gases—burial grounds, slaughter houses, and chandling establishments at our doors, rather than in rendering filth less disagreeable, though perhaps not less noxious, by depriving it of what may be called its *proper* smell, bearing in mind that with the most perfect sanitary condition, we can only expect to obtain in dense populations, a comparative degree of immunity from

disease; and adopting, as a general rule, that all results of experiments put forward by the promoters of remedies, purporting to meet the exigency of the occasion, should be received rather with distrust than too ready an assent.

The notion of the utility of the process of deodrization has received some currency from the publication of the evidence of its advocates, in the Report of the Metropolitan Sanitary Commissioners; but it is one of the *nostrums* of the day, on which we should not recommend the expenditure of public money; for there are no well authenticated facts to prove that putrescent matter can be divested of its injurious effects by the decomposition of the fetid gases, whilst those that are inodorous may be given forth with pestilential effects; and some of the most distinguished physicians, whose opinions may probably be lost sight of, to make room for prejudices more consonant with the cherished ignorance of the timid or interested, have stated, without hesitation, their denial that the so-called disinfectant salts, or any similar substances, possess qualities to effect more than to deodorize animal or vegetable matters; and that fact being established, it is not our desire to throw any doubt on the fertilizing properties of some of those substances used as additions to manures.

It has been adduced as proof of their disinfecting power, that by the use of those chemical substanees, the filthiest cess-pools have been cleaned, and dead bodies, long buried, disinterred and examined for judicial enquiry, without injury to those employed respectively in those duties. But such things have been done before, and are daily done with impunity, without the use of so-called disinfectants; and while these facts point out clearly the peculiar and subtle nature of the maleficent

gases, they also go far to show that it is to their accumulation and continued action on the human frame, without sufficient dilution with the atmosphere, whose currents are impeded in their free circulation in cities, that the greater tendency to disease is in some measure attributable; and this receives corroboration from the fact that there is hardly a cabin in the country parts of Ireland, which would not furnish ample employment to an enthusiastic deodorizer, in the receptacle for every description of filth thrown into the cess pool and dung heap before the door; and yet, neither fever nor other contagious diseases have been peculiarly prevalent in those isolated habitations of the poor, unless as concomitants of famine or of privation, less in degree attended with similar effects; whilst in the Poor Houses, where much attention is paid to cleanliness, the mortality has been great; but that is to be accounted for by over-crowding, and the consequent copious exhalations from the bodies of the inmates—such conditions had been long heretofore observed to be fruitful sources of disease; it was, however, reserved for modern science, to show that the actual presence of organic matter diffused in the atmosphere, and liable to decomposition, is the cause in those exposed for some time to its influence in crowded apartments where its generation is rapid, and adequate ventilation not to be obtained.

If, then, this greater dilution of foul exhalations by the atmosphere, and less accumulation in the agricultural districts, be admitted to be amongst the prominent causes of less mortality than in urban districts, (due allowance being made for difference of habits and occupation,) we have a certain amount of remedy in the measures already laid down, by removing, as far as circumstances will permit, all impediments to the free circulation of air, by

opening out courts, alleys, and confined streets; paying attention to the structural arrangement and permanent ventilation of the dwellings of the poor, and inducing habits of cleanliness, by the increase of facilities in every department; and this leads directly to the consideration of the requirement of the first necessity towards so desirable an end, namely,

THE SUPPLY OF WATER.

The capabilities in this respect are great, and although much has been already done, much is still wanting to improve and extend the means of supply.

In our recollection, the only reservoir was the city basin, near James'-street; this is partly supplied from the river Dodder, but principally from the Grand Canal. Another basin was subsequently formed in connexion with the same canal, at Portobello; and more recently, a third at Blessington-street, communicating with the Royal Canal. We have thus on the west, south, and north sides respectively, on which the city principally extends, ample reservoirs, at altitudes adequate to the delivery of water to the basements of the houses in the highest situations, and containing in the aggregate, 3,051,850 cubic feet of water, equal to 24,414,800 gallons, which, supposing the supply constant, and taking the population of Dublin, at 238,531, the number of inhabited houses at 20,758, and the number of families at 50,625, would give 102 gallons daily to each individual, 1087 gallons to each house, and 480 gallons to each family, being three or four times more than is ordinarily required for domestic uses, and leaving a large surplus disposable for other purposes.

The laying down of pipes of sufficient caliber, in the streets not yet provided with them, and the keeping of the water in the basins to the standard heights, constitute the principal objects to be accomplished. The connexions of the canals with the basins make the latter easily obtained.

The summit level of the Grand Canal is two hundred and seventy-eight feet above low water mark at Dublin; this level is sixteen miles in length, including the branches to the Blackwood reservoir, and to Miltown, from which it derives its never failing supply of the purest spring water. When all the mountain rivers were dry last summer, the trade, by passenger and lumber boats, was abundantly supplied by it, in addition to all other draughts from the canal.

The summit level of the Royal Canal, is three hundred and twenty feet above low water at Dublin; this level is twenty six miles in length, including the supply cut to Lough Owel, which is four feet above the summit. Lough Owel contains nearly three thousand statute acres; it has but one outlet, namely, that which leads to the canal; it is in the catchment basin of an extensive upland district, and has powerful springs within it; and in proof of the salubrity of its waters, is famous for its trout. In the driest seasons, the surface of this extensive lake is not known to be less than two feet above the surface of the summit level.

The ascents of the levels of the canals in the vicinity of Dublin being very precipitous, afford choice of sites for reservoirs adjacent to either or both, as circumstances may require; these being made to communicate with the basins independently of the canal, or otherwise, could be drawn on by sluices, to keep the water to a

standard height. The harbour level being that from which the basins are supplied, the water has been represented as objectionable, from being exposed to impurities from the boats; but this is in a measure corrected by the constant supply of redundant water received from the upper levels by the action of the trade, and also by the overfalls, which admit surface water only into the basins; added to this, a proper filtering apparatus on a large scale, would give all the necessary freedom from foreign matter. If, however, it should be considered desirable to take the water from a source not liable to that objection, and from a level that would command the tops of the highest houses, thereby conferring the many advantages of a powerful head of water, there would be no impediment in the way of it except the cost. A suggestion of this nature was made by us in a letter, published in the year 1844, addressed to the Directors of the Royal Canal Company, pointing out the extended application to purposes of public utility, of the commanding supply at their disposal.

A source of supply not now of much moment, may be rendered important at a reasonable expense, by the judicious improvement of the city water course, which leads a portion of the mountain waters into the Grand Canal.

It will be seen from the foregoing, that the supply is within reach, and all that we want is its proper application; the benefits of which, in promoting general health and convenience, can not be over-stated; but in the midst of this abundance the appliances are wanting to a vast extent; for it appears by the evidence taken by Mr. Commisioner Hayward, that not less than twenty miles of streets have no pipes laid in them; and that the population in these localities are dependant on public

fountains, which are often remote, and add, in severe weather, another pain to the hard lot of the struggling poor—another impediment to that cleanliness, so indispensable to health. Cleanliness may be said to be a virtue. We naturally, as we find it, associate filth with crime; and there is certainly more than a mere figurative relationship between physical and moral uncleanness.

Much importance is properly attached to the purity of water, but we are not disposed to judge of its wholesomeness by mere chemical analysis, nor to set up a preference of one source to another, because of some small per-centage between the solid particles found in different waters; for there is hardly any liquid we use liable to admixture of foreign matter, which being subjected to analysis, that may not yield substances, abstractedly considered unfavourable to health. What we should require is, that water shall not contain injurious quantities of organic matter, or of the salts which produce hardness; the smokey atmosphere of a large city adds saline matter, to water exposed to its influence; the well water of cities receives salts, by the filtration of impurities from the surface through the earth; and rain water itself, is likewise impregnated, as it passes through impure air; but it is only in excess that those matters are hurtful, their presence being inevitable to a certain extent; the test of experience, and the evidence of our senses, are generally found to have established that which science subsequently confirms and explains. Ancient Rome, centuries before chemistry deserved the name of science, had the practical benefit of combined systems of water supply and sewerage, whose magnitude and excellence are admitted, but not equalled by any city of modern times.

The structural improvement of the dwellings of the poor, as we find them put forward in plans of model lodging houses, with baths and laundries attached, are matters, however desirable, that must wait for better times, at least in this country. Much benefit can, however, be obtained in the mean time, at a trifling cost, by ventilation, in making small apertures in the upper and lower parts of each room, and inserting a tube in each aperture, divided by a perforated plate of zinc; the tube to be closed in very cold weather, by a wooden stopper. This, which is a simple plan proposed by Dr. Collins,* is deserving of attention; and we trust when the people shall be made to understand its advantages, that it may be generally adopted.

The ventilation of the houses of the better classes, is gradually receiving that increased attention which the importance of the subject demands; but as yet much success does not appear to have attended the experiments on a *great scale* made elsewhere on this subject, as applicable to public halls of assembly, owing, possibly, to the want of sufficient dissemination of the means of ventilation; the currents of air becoming sensible in their rush, to compensate for rapid rarefaction. This may probably be remedied by the mode adopted, as Vitruvius states, by the Greeks and Romans, who, in their buildings, carried up the external and internal, walls separately, except where it was necessary to have them held by ties and bond stones; thus forming an air chamber within the walls, at every part of the building, capable of keeping up, by well regulated means of admission and egress, that *imperceptible* interchange of

* Observations on the prevention of contagious diseases, by the effectual ventilation of the houses of the lower classes. 1848.

fresh with impure air, by which an adequate system of ventilation can alone be obtained, and without the necessity of the introduction of the excessive quantity of air set in motion by the modes usually adopted. This plan would likewise prevent the communication of cold and dampness from the external wall to the internal one; and the temperature of the latter being the same as that of the apartment, there would not be any condensation of vapour, which spoils decorated walls, and produces dry rot in the studding used to counteract the injurious consequences of *weeping;* and it seems not improbable, that the preservation of their beautiful fresco paintings from injury by a similar cause, may have led the ancients to take effectual precautions against its clouding and defacing effects on the unabsorbing surfaces of their polished walls.

Without pretending to offer this as a plan for general adoption, we thought it not unworthy of a passing observation, incidental to the subject, and possibly applicable to the ventilation of public assembly rooms, where a combination of causes tend to the rapid production of overheated and impure air.

Sanitary improvement in all its dependencies is undoubtedly one of the great questions of the day. The increase of the population in cities and manufacturing towns, and the certainty of railway communication adding to that tendency, give increased importance to the subject; and when we consider the expense of fever hospitals, maintained at the public cost, and the mysterious propagation of diseases, from a bad and poor locality to the well circumstanced dwellings of the rich, there are stronger motives than mere philanthropy for the adoption of well considered comprehensive plans of improvement,

embracing all that is wanting to make a reasonably perfect system, which might be gradually carried out, according as the necessary priority of some of the works, and the urgency of others, might dictate, but each tending to the ultimate combination of the whole; and not halting in our efforts in the absence of imperative necessity, which unhappily is too often found the only enduring motive of amelioration.

[May 9th, 1848.]

An account of a Carriage carrying its own rails, invented by Mr. H. Wrigg, to be economically used in carrying soil upon bogs. F. V. Clarendon, Esq., A.B., M.R.I.A., Secretary.

Mr. Clarendon brought under the notice of the Institution, the subject of a "Locomotive Railway," which had been the invention of the Messrs Wrigg, and had occupied many years' consideration.

Mr. H. Wrigg (who was present) exhibited a well executed model of the invention, and explained its object.

The object sought to be accomplished in the first instance, was confined to the carriage of fertilizing soils upon bogs; to this, was afterwards added the employment of steam, as a motive power, on ordinary roads, and the transit of goods and passengers across the Isthmus of Suez, formed part of the inventors' views.

The design consisted in making every description of carriage carry its own rails, and (contrary to the ordinary course) the rails were caused to slide upon wheels, which were supported on pedestals, attached to, and forming part

of an endless chain or belt, revolving upon drums, in such a manner, as to present to the rails a continuous succession of bearing wheels, the rails being immovably fixed to the bottom of the carriage. The bases of the pedestals could be constructed of such an extent (with but little increased friction) as to present an area to the surface, incapable of being forced into it by an ordinary weight.

It was conceived by the inventor, that the principles of the construction of this machine would render it capable of moving with equal facility upon a soft bog, or uneven road, as upon an unyielding surface; abrupt obstructions in a road were sought to be overcome, by giving the ends of the rails a curved form, so as to convert the obstacle into an inclined plane.

Steam was the motive power intended to be used, and the turning or guiding part of the machine was confined to the front carriage, which supported the engine.

The peculiar construction of the machine, economised the cost of wear and tear, as the engine was mounted in such a manner, that the drums (which were the driving wheels) were caused to yield to any inequalities of the surface, simultaneously with the engine itself.

The machine was stated to possess the additional advantages of facility of ascending any gradients, and economy in construction.

Mr. Wrigg further described the amount of friction to be overcome.

Mr. Alexander Deane, (Member) submitted, for the consideration of the Institution, a plan for cleansing the bed of the River Liffey, as the main sewer of the City of Dublin. He proposed to employ a small steam vessel of light draught of water, having her paddles fitted with whalebone sweeps, similar to those used in the London street-sweeping machines. This vessel was to be used at the last quarter of the tides, when by disturbing the foul deposit on the bed of the river by the action of the sweeps, the force of the current would carry it into the deep water. The action of the sweeps would be found most effective after heavy rains, when the increased velocity of the current would facilitate the operation. The steam vessel should also be constructed as a dredge, and thus be rendered more available for the services or the port.

Mr. Isaac Farrell (Member) exhibited a model of "Balance Gates," which he conceived might be usefully adopted in connexion with regulating weirs, in navigation or drainage works. These gates were designed on the principle of the ordinary self-acting sluices, and were so contrived, that the rise of the water in the reservoir regulated the power of discharge, and upon the fall of the water to the level at which it was intended to be retained, the gates returned to their original position, and formed portions of the regulating weir.

THE PRESIDENT exhibited a drawing of an Earth Excavating Machine, designed by Mr. Moriarty. This machine consisted of a series of picks, eight in number, similar in their form and mode of working to the ordinary pick, but much larger, and so arranged as to cut and loosen the earth in front of the machine. The earth so loosened, was afterwards scraped up, carried back, and thrown into waggons placed underneath, by means of a number of buckets or scoops, worked in a similar manner to the ordinary dredging machine. By this means a passage is cut, in which, as the excavation proceeds in front, the machine itself advances by a motion given to the back wheels, the entire being driven by a twelve horse-power high pressure engine. The saving to be effected in the execution of heavy excavations by the use of this machine, instead of manual labour, was stated to be very considerable.

[June 6th, 1848.]

The Self-regulating Hydro-anastatic Sluice; by WILLIAM FORSYTH, ESQ., Member.

THE model submitted for the inspection of the Institution, was constructed to explain to the Commissioners appointed under the Drainage Acts, the working of a series of sluices, proposed to be erected at Belleek, in the County of Fermanagh, for the purpose of regulating the surface level of lower Lough Erne. To comprehend the design, it is necessary to premise, that the lower Lough Erne is the final receptacle, before its discharge at

the outfall, of the surplus flood water of a rain basin, comprising within its boundary, an area of 1521 square miles, or 973,440 statute acres. The quantity of surplus or drainage water, flowing from this extensive basin in the wet season, or after excessive falls of rain, has been ascertained, by observations extending over a period of more than two years, to amount to 700,000 cubic feet, to be discharged each minute at Belleek, where the outfall is situated. The surface area of the lower Lough is small in proportion to the area of its whole rain basin, being only in the ratio of about one thirtieth; and from the peculiar circumstances affecting the district, it is necessary that the range in the surface levels of the Lough should be confined to within about twelve inches. The limited area at the outfall, within which the regulator must be constructed, does not afford space for an overfall or weir, having a discharging line of sufficient length, to pass the ascertained quantity of flood water, under a head coming within the above stated range; therefore it became necessary to have recourse to a system of sluices, affording a discharging power equal to the exigencies of the case.

The peculiar properties of this sluice specially adapt it to the situation; it has therefore been submitted to the Commissioners for adoption, in the event of the works of the Lough Erne district being carried into execution.

It is proposed to construct a regulating weir of about eight hundred feet long, of solid masonry, divided into lengths by piers, in three assemblages. The piers in each assembly to be placed twenty feet apart in the clear, and the sills in the spaces between them, to be eight feet below the level of the coping of the solid parts of the weir between the assemblages. The proposed number of

these openings is seven. In each opening it is proposed to fix a hydro-anastatic sluice—a modification of the sluice gate known in America by the name of the "Bear Trap Sluice." The gates are furnished with double leaved valves fixed in chambers constructed in the solid of the piers, opening into the conduits underneath the gates, and communicating by culverts with the head water above, and with the outfall below the weir.

The chambers in the piers are separated into two divisions by a partition, in the character of an overfall or small guage weir, the top of which is a few inches over the level of proposed summer water. When the head water enters the first division of the chambers, by the culverts, it presses back the smaller leaves of the valves, and enters the conduits underneath the gates; by which means they are raised by hydrostatic pressure to the level of the coping of the solid parts of the weir.

When the level of the head water is raised a few inches by floods, the water passes over the partition into the second division of the chambers, and presses on the larger leaves of the valves, by which the pressure on the smaller leaves is overcome, and the communication opened from the conduits under the gates, to the outfall by which the water sustaining the gates passes off, the gates then fold down level with the head sills, and give free vent to the flood water to pass over them. When the level of the head water falls to that of the solid weir, it ceases to pass over the partition into the second division of the chambers, and the water remaining in this division passes off to the outfall, by a small hole in the centre of the leaf, thereby removing the pressure altogether from the larger leaves; the smaller leaves are then pressed back, the communication with the outfall cut off, and the water

enters the conduits under the gates, by which they are again raised to the level of the solid weir, or proposed summer water. The level at which the water enters the second division of the chambers is governed by a moveable guage board attached to the upper part of the partition, which can be set to the proper level to make the gates self-regulating; but to give complete control over the valves at all times, it is proposed that the shafts on which the valves revolve, shall rise above the coping of the piers, and be furnished with capstan heads, or bevel wheels and pinions.

To afford access to the gates at all times, it is further proposed to construct a light timber foot bridge, supported on brackets over the solid weir, and trussed over the openings between the piers, It would be very difficult to give a proper idea of the construction and the manner of working of these gates in the absence of a large number of detailed drawings; it is therefore presumed that the above general description will be sufficient, as an inspection of the model, which is constructed to a scale of one inch to a foot, will fully explain every part.

[November 14th, 1848.]

An account of a Three-Sided Coffer; by M. B. Mullins, Esq. A.M., Member.

In constructing the lock for the navigation at Athlone, under the Shannon Commissioners, it so happened that sufficient provision was not made in the side walls of the chamber for the reception of the traverse rollers of the gates, so as to permit of their being opened back within the recess; and this omission was not discovered until the works had been completed, and the water admitted within the lock. It then became a subject of grave consideration, to determine as to the best and most economical manner of executing this difficult operation. The obvious method of putting dams in the stop gate grooves, would be attended with considerable delay and expense; and from the porous sandy nature of the bottom, not altogether without risk, had an attempt been made to unwater, by placing pumps in the chamber, which was the only mode that could then be adopted, as the whole of the means had been removed, including ten metal pumps, each fifteen inches in diameter, a steam engine and three water wheels, whose combined power amounted to about fifty horses, indicating the difficulty that existed (during the construction) of unwatering the work.

The plan of performing the operation with the diving bell, involved so much delay and expense in procuring, erecting, and working the bell, as to render the adoption of such a course imprudent, if not impracticable, from the depth of sinking required to be made in very hard stone, and the disadvantage at which a long chisel reaching

from the bell, would be brought to bear on the work. The diving helmet was also considered quite inapplicable, as a sufficiently forcible blow could not be given by the hand and mallet striking in water. Under these circumstances, it was conceived that a timber case might be so constructed, as to include between its sides and the wall, merely sufficient space for a man to work in, and that the water might be readily pumped from the limited enclosure. Accordingly, after some consideration, a coffer was constructed without top or bottom, and with three sides only—the side wall of the lock being intended to supply the place of the fourth side. It was formed of three framed ribs, properly braced, upon which were fixed the sheeting planks of the chest, closely jointed and carefully caulked. A double fold of cotton cloth projecting externally, was tacked to the edges of the planks which were to come in contact with the side wall, in order to aid in producing staunchness, and a leather flap, similarly projecting, was attached to the ends of the sheeting intended to rest on the recess floor. It was necessary to notch the sheeting, in order to make room for the traverse plate, which otherwise would have prevented the chest resting level on the floor, and the leather flap was carefully continued in this notch.

The coffer being thus constructed, heavy metals were placed on the lower rib, to counteract the floating power of the timber, and it was then sunk in nearly ten feet of water, in close contact with the side wall, some management being necessary to bring the notch so as exactly to fit on the traverse plate; this being done, two hand pumps were put down, one in each external angle of the chest; these were rapidly worked. Buckets were also used in the first instance, in order to expel the water

quicker than it came in, so that the pressure from without might force the edges of the chest tightly to the wall; puddle clay was thrown on the bottom near the leather flap, and at the sides where the folds of calico projected; in a little time it was seen that the plan was successful. When the water had been reduced to the level of the lower frame, the metals were removed, the pumps which had rested on these metals were placed on the recess floor, and the enclosed space being rendered completely dry, the required work was soon effectually accomplished.

This plan is applicable in other cases, as for instance, in the repairs of the floors or invert of a lock chamber by the addition of the fourth side of the chest.

On the Ballyteigue Drainage Works, by* W.T. Mulvany, Esq., Vice-President.

Mr. Mulvany brought under the notice of the Institution, the change which the drainage operations of Ballyteigue have effected in the time and height of tides within the Lough.

The design adopted for the reclamation of the slob lands at that place, consisted chiefly in the construction of an embankment across the Lough, in such a position as to shut out from the tidal action a space of about one thousand six hundred acres. The project was very fully considered, and excited much discussion when first submitted to the public; many persons were seriously

* An account of the original projected works for this very important Drainage and Navigation measure, is given in the Transactions of the Institution of Civil Engineers of Ireland, Vol. I.

apprehensive that the proposed works would iujuriously affect the navigation; some eminent engineers reported unfavourably of the measure; and a long correspondence took place with the Admiralty on the subject.

A great irregularity existed in the time and height of tides within the Lough, as compared with their level and time outside in the sea; and this arose from the peculiar construction of the estuary, which rendered it necessary that a large expanse of two thousand two hundred acres should be filled and emptied, through an extremely narrow and long entrance at the bar. The result was, that the difference of time between the high water of springs at the bar and at "Ring's Nook," a point 6¼ miles distant, was two hours and eight minutes; while the rise of spring tides over the surface of the Lough was lower by from two to three feet than that of the sea outside. The advocates of the measure maintained that the result of diminishing the tidal basin and deepening a few shoals, would, in a great degree, tend to equalise the height and times of tide inside and outside the Lough; and, consequently, that so far from the scour over the bar being injuriously affected, a much improved communication would be formed, as the counteracting forces that existed at the mouth would be destroyed, and an inward and outward current created, in conformity with the rise and fall of the tide, which would tend effectually to the removal of the obstacle at the entrance. It was very gratifying to be able to state, that for so far as the works had been carried on, the anticipations as to their effects upon the tides had been fully realised.

For the purpose of excluding the tidal waters from the upper portion of the Lough, and for future facilities in constructing the lower works, an embankment had

been completed at "Ring's Nook," three miles further from the bar than the great embankment to be hereafter raised; and the results, reported by Mr. Smith, the able engineer in charge, were in the highest degree satisfactory. It was ascertained by accurate levels, that a rise of fourteen inches at spring tides has resulted at "Ring's Nook," and an actual additional fall of two feet three inches below the former line of low-water; while the difference of time in the occurrence of high water at the bar and at "Ring's Nook" diminished from two hours and eight minutes to one hour and forty minutes; thus, as was anticipated, an increased rise of high-water, an increased fall of low-water, and a diminution of the difference of time, have been effected; and these results gave hope that when the works were fully carried out, their completion would realise all the anticipations that had been put forward, as to the uniformity of the tides within and without the Lough, and the other beneficial effects that would result to the navigation.

[February 13th, 1849.]

An account of the Construction of the Woodhead Tunnel, on the line of Railway between Manchester and Sheffield; by W. A. PURDON, ESQ., Member,

THE SITUATION AND CHARACTER OF THE WORK.

THE tract of country lying between Manchester and Sheffield is traversed by a well-known ridge of mountains, called the Pennine chain, and sometimes the back-bone of England, in which the rivers Dun and Mersey take their source, and flow in opposite directions to the eastern and western shores.

When the plan of a railway for connecting the towns in question was required, it was early seen that a tunnel through this ridge was unavoidable; and it was also perceived that the best place for getting it through, was near the head waters of the rivers that have been named, as their gorges penetrated further up, and presented the narrowest limit of the ridge, and their courses downwards through the flanks of the mountain, afforded the most desirable route for the railway. This position was found to be nearly midway, and not much out of the nearest direction between the two towns. The railway between Manchester and Sheffield, merits some notice, not only on account of the work I am describing, but for its general design and bold works. The tunnel is situated at the summit level of the railway, which falls both to Manchester and Sheffield, with inclinations equal to about forty feet per mile on either side, for eighteen miles. Such gradients had at the time a degree of novel severity; but they afforded the best way by which the great

elevation could be reached, at which it was practicable to commence the tunnel.

It has been stated that the route of the railway followed the courses of the river Dun and Mersey. This description is entirely true with regard to the river Dun. Its approach to Sheffield enabled the railway on its banks to abut upon the town. It was not so upon the Manchester side. The river Mersey passes wide of that town, which involved another tunnel of difficult construction through the ridge at Hattersley, which separates the waters falling into the Mersey from those into the valley of the Tame, as the line approached Manchester. There were also the Dinting and Etheron viaducts, two structures of unusual dimensions, designed by Alfred S. Jee, Esq., and considerable viaducts, over the lateral brooks of the valleys traversed, together with heavy embankments and culverts on sidelong ground, and deep excavations; so that the line may be said to have been one of heavy and difficult works, which have been happily overcome.

GEOLOGY OF THE RIDGE.

Having described the situation of the tunnel, it is desirable to explain the character of the formations through which it had to be carried, as this is often of more consequence, in regard to the construction of such a work, than its physical magnitude. The measures passed through were beds of grit, various sandstones, and different qualities of shale. The order in which these strata occur is well known—resting upon the limestone, the coal series, passing up through its various beds of grit and sandstone, alternated with argillaceous

shales, reaches the lowest seam of workable coal known in Yorkshire, immediately below which, lay the whole of the measures that had to be operated upon in driving the tunnel. The disposition of the strata showed a moderate dip to the eastward; but it is not to be inferred that the sheets of rock around, and overlying the tunnel were in one continuous plane. They lay in the usual masses of irregular form and area, with various inclinations, and insulated by faults, (see plate VI.) There were no organic remains, or mineral ingredients discovered, but those well known in the coal measures; and the only observation worthy of remark with regard to this lower portion of the series (which is not so familiar) is, that there was no absence of the usual developments which occur in the upper measures of this class of rocks.

GENERAL DESIGN AND STRUCTURE.

It has been stated that the tunnel is situated at the summit of the line. The height of the rails at this point is nine hundred and sixty-six feet above the sea, and marks the eastern entrance. At the western end, the rails are but eight hundred and eighty-seven feet above the same datum, which shows a difference of level, between one end and the other, of seventy-nine feet. The distance between these limits is three miles and fifteen yards, the total length of the tunnel.

The stratification has been described as dipping eastward. The gradient of the tunnel rises in the same direction, with a uniform inclination from end to end, of one in two hundred.

From the first, it was laid out to have two parallel

tunnels of smaller dimensions, instead of one larger, and calculated for a double trackway. This was determined in order to save immediate outlay, with a view of constructing but one of the tunnels in the first instance, and leaving the second one in abeyance until increased traffic should require its construction. This practice deserves commendation, with respect to tunnels of such magnitude as that I am describing, not only from the lesser difficulty of raising the smaller capital, but in consequence of the lesser quantity of excavation requisite to be drawn from the limited number of faces of operation used; and it does not appear to me that the ultimate cost of the two tunnels should generally exceed that of the larger size, if the ground be at all of a friable nature. The thickness of the space between the two tunnels, was designed at seventeen feet, and that lying the more southerly was the one executed, and to which the observations in this paper refer.*

The clear height of the tunnel is eighteen feet, and its width is fifteen feet. The form of the arch is a semi-ellipse sprung from the ends of its conjugate axis, resting upon vertical sidewalls. The course of the railway is straight through the summit ridge, and the centre line naturally falls between the two tunnels before described. It was upon this line that the shafts were sunk, so that they were situated on a parallel line, sixteen feet off the centre of the tunnel under discussion. The highest point of ground shown on the longitudinal section of the summit ridge (see plate VI.) is one thousand five hundred and fifty-two feet over the sea, and six hundred and twenty feet above the tunnel formation. The two entrances were

* The second tunnel is in course of construction at present, and is about half finished.

fixed at an extreme depth of sixty-five feet of open cutting, which was heavier at the eastern face, owing to the ground rising less precipitately.

In consequence of the great depth from the surface to the level of the tunnel, it was calculated that but little time, in proportion to the expense, would be gained by sinking many shafts in addition to opening each entrance face. Accordingly it was determined that there should be but five shafts sunk. The position of each shaft was fixed so as to bring all the various headings of the tunnel to a termination at the same time, or as nearly so as rational pre-judgment could determine. The manner in which they were disposed is as follows, (see plate VI.)

			Yards.
From western face	to	No. 1 shaft	1160
,, No. 1.	to	No. 2 do.	825
,, No. 2	to	No. 3 do.	648
,, No. 3	to	No. 4 do.	748
,, No. 4	to	No. 5 do.	748
,, No. 5	to	eastern face,	1166
		Total,	5295 lineal yards.

The depths of the shafts are as under, expressed from the original surface to the level of the rails.

	Yds.
No. 1 Shaft	182
No. 2 do.	189
No. 3 do.	162
No. 4 do.	189
No. 5 do.	135
Total,	857 lineal yards.

From which it appears that the average depth may be taken at one hundred and seventy-two yards.

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PLAN OF CONSTRUCTION.

It was resolved to drive two driftways, one at the top, the other at the formation level of the tunnel, through the entire length, before commencing the general excavation. The size of these headings was—for the top one, four feet, and the bottom one, six feet square, (see plate VII. fig 2.) The object of this mode of proceeding was, to meet some points of difficulty that were presented. (The mode of ventilation will be subsequently explained.) It served as a means to carry air to the workings through the long stretches that lay between the various shafts and open ends, as is usual in coal works, by horizontal and parallel galleries ; so by placing one of the drifts vertically over the other, the same effect was obtained. The upper one ranged the crown of the tunnel, and laid open the work for final excavation, while the bottom one served for the drainage and drawing away the material, and both together lessened the quantity of excavation to be afterwards raised, and took off the water from the heavier work of the enlargement. Further, there was pecuniary reason. It was not thought wise to go too headlong into so great and novel a work, when by merely driving driftways, a lesser sum of money was expended in the first instance, and when the headings were gotten through the problem was solved, so far as regards the amount of water and knowing the nature of the ground : confidence in the undertaking was established, which enabled the work of greater size to be pushed more vigorously afterwards ; and for these reasons it was preferred to drive a double driftway throughout, before carrying the full excavation forward, or following close after the headings.

The number of shafts, and the manner in which they were disposed, have been already stated. They were ten feet in diameter; and a twenty-five horse engine was applied at the top of each to wind out the material, and work the pumps. It was assumed that the sinking would occupy about fifteen months, and that in the mean time the headings from the entrance faces would be advanced by as much as the greater lengths of those stretches exceed the distance between any two of the shafts; so that after the horizontal work should commence from the bottom of the shafts, the entire number of faces of operation would have equal spaces* to drive before meeting the headings from the opposite direction, and thus leave the mountain thrilled at one period of time. It was then proposed to follow up with the widening process and general formation of the tunnel at each face. The plan of ventilation will be detailed; but it may be observed that there was no want of air felt after the communication was opened by the drifts in the way described, between the respective shafts and the open ends of the tunnel. It was only until the headings should be gotten through that any artificial means were requisite.

PRELIMINARY OPERATIONS.

A company was formed in 1836, and the act for the construction of the railway, embracing this important work, was obtained in May, 1837. It was twelve months afterwards before any steps were taken for proceeding,

* The spaces, said to be equal, are not to be taken necessarily as being exactly so; the hardness or softness of the ground would upset the effects of so refined an adjustment.

owing to the formidable nature of the undertaking. The promoters were not assured, and had to contend against the opposing views of timid and dissenting shareholders.

The engineer, who laid out and entered upon the construction of this work, was Charles Vignoles, Esq. He was superseded by Joseph Locke, Esq., under whose direction it was executed.

The ground was broken on the 1st October, 1838, but nothing of a determined nature was done until towards the end of the following year.

The preliminary works that were necessary for commencing the tunnel were not so trifling, or such as might be done at once. It was necessary to make cart roads, in different directions, to convey coal for the engines from the adjacent public roads, and also to connect the various points of operation, the united length of which exceeded four miles. It was requisite to build cottages for the workmen, stables, a gunpowder magazine, and workshops; besides erecting the engines and constructing the reservoirs, observations, &c.

It may not be wrong, at this place, to state a few particulars of the notions that prevailed at the time in question, with respect to a work of this nature.

It was generally said that it would never be made, or that if it were, it must be at an absurdly extravagant cost after many years. The opinions of those most interested were very vague, and but few had any idea of how long it would take to construct, or how much it would cost. It was thought, however, by those best able to form a judgment, that the strata were generally favorable, from the appearance of the bassettings and dip, along, and in the vicinity of the line; and that passing boldly, as it did, under the centre of the ridge, there

should be no ground of a highly broken and contorted character, or (as in sidelong ground,) that might occasion a creeping weight, and require expensive timbering and lining for its support. The circumjacent valleys lay in such a manner, both in point of position and levels, in respect to the drainage of water from the workings, and the fact of the tunnel being situated nine hundred feet above the sea, led to the belief that the quantity of water from the natural drainage of the surrounding district would not be excessive.

It was also seen that the time of completion must be governed by the mode of construction that might be employed, and that, owing to the great depth of the shafts, the number of faces of work most likely would be but few, which shadowed forth in some degree the period for its completion.

THE RANGE AND LEVELS.

The setting out of the line of the shafts, and transferring the range and levels into the interior of the hill, was a practical performance of some nicety and consequence, which was entrusted to the author of this paper.

The two ends of the tunnel were determined by considerations relative to the approach of the railway; and it was necessary, in the first instance, to connect the two points in question by a straight line passing across the summit ridge. This was readily affected by means of a theodolite. A line, starting from one of the points, and directed towards the other, was carefully ranged and measured through a succession of station points, (ten in

number) situated in the line, upon the most prominent features of the ridge. The distance from the beginning of the line to each station was noted, as well as the point at the end abreast of the other entrance. It was found that the line, thus set out, passed ninety-two feet wide of the required point. Then by similar triangles, as the extreme length of the line measured is to ninety-two feet, so is the distance up to each station to the length of lateral shift into the line required. A row of ranging rods were then placed in the points thus found, and by a few trials with a portable transit, were soon adjusted so nearly into a straight line, that it was found afterwards, by more refined means, to be but two inches out.

Upon the line thus set out, four observatories were erected, between thirty and forty feet high, one of which was at the summit point, and the other at the leading points of the escarpments, by which means the whole range across the hill was observed, and a view commanded of every shaft, at no greater distance than half a mile from one or other of the observatories. These were round towers, thirteen feet diameter, with a concentric pillar carried up within, and a stone table placed on it for the transit to rest upon. There was a winding staircase leading up to the foot of the stone table, at which level a floor was placed. Neither the floor nor stairs were any where in contact with the centre pillar. The outer walls of the tower were carried up about eight feet higher than the floor, and the whole was covered in with a flat leaded roof, surmounted by a coped parapet. Windows opened upon the range of the tunnel in opposite directions, and the chamber inside was protected from the high winds, and the instrument freed from vibration.

There was a telegraphic arrangement attached to each

tower, for indicating the movements required to be made for the adjustment of the necessary points upon the range.

Transits of thirty inches focal length, and 2¾ inch object glasses, and stands with lateral slide motion, were applied upon the stone tables, and brought to bear upon the sight objects in the various observatories, and upon the back ranging stations which were built opposite the tunnel entrances, by which means the line was ranged with the utmost accuracy, and the centre of the shafts determined.

It has been stated that the line of the shafts was sixteen feet off the centre line of the tunnel. It hence became necessary to fix two points upon a parallel range, by means of which, the entrance stretches from both ends should be driven. This was done by setting out two fixed points near both entrances upon the line of the shafts in the most convenient positions, and mechanically squaring off the sixteen feet, which gave the requisite points upon a parallel line that covered the range into the tunnel.

In order to pursue this part of the subject, the sinking of the shafts and other horizontal work may be supposed completed, and it remains to describe the mode of transferring the lines and levels into the interior.

The shafts were carried down truly vertical, by means of a plumb line with a traversing rod of the same length as the radius of the shaft, which was applied to every stage of the sinking. The depth was calculated, and the following is the manner in which it was measured, so as to set out the formation level of the tunnel at the bottom :—

There was a segment of each shaft set apart for

the pumps, and divided off by a brattice or partition of boards, nailed vertically against the cross beams that were placed to support the pump trees. A vertical stripe was drawn down the face of the partition, by means of a plumb-line; and along this stripe, the measurement was carried by a lath thirty-one feet long, with a hole bored through, near either end, so as to leave the distance between the centre of the holes, thirty feet exactly. A set of spikes made of wire, (¼ inch size) thick enough to fit easily into the holes of the lath, and about three inches long, were procured. These spikes were without heads, and one of them partially driven into the top part of the partition, and its relative level ascertained.

The lath was then hung upon this spike, through the hole at one of its ends—the other end being suspended within the shaft. A man went down by the winding rope, as far as the lower extremity of the lath, and drove into the partition another spike, through the hole in the lower end of the lath. He then jerked off the lath from the upper spike, which remained fixed, and letting the lath slip down through his hands, hung its upper end upon the second spike, and descending again, drove a third spike into the partition through the lower end of the lath which he jerked off the spike next above him, and so on to the last, observing to note the number of spikes driven, as a surveyor would the arrows of his chain. When arrived within thirty feet of the bottom, a bench mark having been fixed, its depth from the last spike was measured by a two foot rule on the lath. The level of the bench mark was then reduced to the general datum, and the formation level of the tunnel at the bottom of the shaft was cut out accordingly.

The levels at the bottom of the shafts, and at the two

entrance faces, having been carefully checked, there was no difficulty in carrying the right inclination through the tunnel, in the same way as any gradient on an open road, only that it was necessary to use a level, having an aperture at the side, in order to light the cross wires artificially, there being no sun-light to come in at the end of the telescope. It was found convenient to use a staff with the vane contrived to show a horizontal slit of light from a lamp behind.

The getting down the line of range through the shafts was performed in the following manner. A deal plank, having one of its edges shot straight, was prepared and had fitted upon the side two reels, capable of holding each a coil of $\frac{1}{16}$ inch copper wire, sufficiently long to reach to the bottom of the shaft. The reels were secured upon the plank and placed about seven feet asunder. The plank was then laid horizontally on a frame erected over the mouth of the pit, having the reels on its upper side, (see plate VIII. fig. 6.) It stood eight feet above the surface of the ground. The plank was then brought into coincidence with the tunnel range, and so placed that the wires rolling from off the reels, with plumb-bobs attached, passed over the straight edge and descended on opposite sides of the shaft, in the centre line of the railway, in the position that gave the longest base line the diameter of the shaft admitted, when thoroughly free from any contact with the sides. The coils of wire were then payed off the reels by the weight of the plumb-bobs, which were leaden globes, weighing each 35lbs., and governed in their descent through the shaft, by two men at the reel handles.

The manner in which the end of the plank was brought into range, was by suspending a line and weight from

above the level of the plank, and letting it hang into the shaft for a short distance down. This line was adjusted to the centre of the shaft by means of the transit from the nearest observatory, and the straight edge of the plank was laid up against it, so as it might be said to pass through the centre of the shaft. Then by the naked eye, the edge of the plank thus touching the plumb line, was made to fall, as near as might be expected, into the line of range. A ranging rod was then fixed in the line of the observatories on each side of the shaft, at about three hundred yards therefrom, or such other distance as it was convenient to see distinctly from the shaft, by reason of any rise or dip or other obstruction presented by the ground. The line and weight suspended in the centre of the shaft were then removed, and the side of the plank, at either end, was struck lightly with a hammer, until the two suspended wires were seen by the naked eye when viewed a little way below the level of the plank, to cover the ranging rod on either side of the shaft, after which the plank was cramped securely down.

Passing from above ground to the bottom of the shaft, it was seen there was no entanglement or twitch throughout the entire length of the suspended wires. The plumb-bobs were let down to within fifteen inches of the bottom of the shaft, and immersed in vessels of oil* to free them from vibration, and prevent the drops of water that showered down the shaft, and the currents of air, from interfering with their settling into a state of steady tension.

From the short space of about seven feet nine inches,

* It is well known that oil resists the agitation of water better than any thing else.

and in one instance only four feet three inches, thus obtained at the bottom of the shafts, the lateral distance of sixteen feet was squared off mechanically, by a straight edge and right angle, and two points fixed at the parallel range of the tunnel. It now remains to observe that the lines and the levels carried in through the various shafts and entrance stretches, met those from opposite directions, in a most satisfactory manner. The deviation, in no instance, exceeded three inches, and in some cases only one inch; a degree of accuracy more refined than was found applicable at all times, in settling the leading frames of the various lengths of masonry, as the lining proceeded, so that it was as accurately performed as need be.

VENTILATION OF WORKS.

It is known that in sinking a shaft vertically, or driving a heading, either level or inclined to the horizon, a deficiency of pure air is felt after proceeding some distance, in consequence of the gases that are set free. It was therefore necessary, when driving the entrance stretches, to create a circulation to the face of the work, as it proceeded. This was contrived in the following manner. It has been stated, in describing the mode of construction, that two driftways were driven, one at the top and the other at the bottom of the tunnel. An air shaft, five feet diameter, was sunk on the centre line, at a short distance from each entrance, (before the thickness of the rock overlying the tunnel exceeded materially that at the face,) until it reached the upper driftway of the tunnel. At the top of this shaft a

furnace was constructed, with a flue and chimney in continuation, and when the air at the furnace became rarefied by the heat, the denser air began to rush from the bottom of the shaft, which caused a current from the face of the tunnel to pass through the upper driftway and air shaft to the furnace, and get off through the flue of the chimney. The open end of the upper driftway was then carefully closed up, so as not to admit air, and from time to time, as the work went on, at intervals of about twenty yards, a connexion shaft, 2½ feet wide, was driven between the two driftways, observing to close up carefully the last one, whenever a fresh connexion was formed near the working face.

A current from the entrance of the tunnel, through the bottom driftway, was thus made to circulate up to the face of the headings, and returning by the upper drift and air shaft, passed out by the furnace in the way described.

By this means pure air was maintained in the end stretches, so far as there was occasion to drive, and it was thought possible to have driven much further in the same way.

This principle might have been employed in the stretches at the bottom of the various shafts, by applying a square pipe of wood (twelve inches) up along the shaft side, from the upper driftway of the tunnel; and when it reached the top, an iron pipe of the same area could be added on and carried to the flue of the engine fire. This plan was not adopted, as a system of blowing air into the headings, through pipes, by a fan worked by the engine, was known to have acted successfully in other instances; although experience had not taught its effects in stretches so lengthened as those of this tun-

nel. It however served the purpose, only perhaps less effectually than might otherwise have been done.

The mode in which the air was forced down the shafts by the fan, was through a square wooden twelve inch pipe which branched off into two others of the same description, directed towards opposite ends of the tunnel, through the bottom driftway, up to near the face of the headings. A piece of pipe twelve feet long being added from time to time, as the headings advanced.

DRAINAGE.

The drains for carrying off the water permanently were easily arranged, in consequence of their being an incline of one in two hundred throughout. It was only necessary to make a covered drain down the centre of the tunnel, or otherwise two side drains. The latter was preferred, and two open drains were provided, as shown by the transverse section, (see plate VII. fig 2.) The size of the permanent drains was not of course determined, until observation enabled a judgment to be formed as to the quantity of water, after the mountain was thrilled.

Association attaches to a valley three miles long, a considerable brook in the bottom, and in order to let as little water as possible pass down the tunnel, an outfall, in the shape of a covered drain, was carried up from a lower level in the valley at the eastern face, until by cutting six feet deep at the entrance, its bottom merged into the incline of the gradient, at about two hundred and forty yards inside the face of the tunnel, from which point the water flows out at the eastern end. Towards

the lower end of the tunnel, the quantity of water was of course greater, and it was necessary to give increased dimensions to the side drains, which was done by adding to the depth, instead of increasing the width, owing to the confined limit for the ballast not conveniently admitting any other way.

It was not unreasonably imagined, that after the driftways were through, no further necessity should exist for drawing the water artificially from the workings. Such, however, was not the case, except in the stretch from about one hundred and eighty yards east of No. 2 shaft to the western face. The water was not permitted to pass down the tunnel, while the widening, excavation, and lining were progressing, because it interfered with the getting in of the foundation of the side walls, and otherwise obstructed the proceedings, so that the water was drawn off by pumps to the latest period.

It is, however, right to state, that had proper arrangements been made in time to obviate the inconvenience referred to, the water might have passed down without detriment, during the operations.

The mode of permanent drainage having been stated, it remains to explain how the works were kept clear of water during the construction.

It is manifest, from what has been said, that in driving from the western face, the water had a natural outfall from the first. It was not so, however, at the eastern end, owing to the descent in the tunnel. An outfall was carried up, as before stated, which took back the water for two hundred and forty yards. Here it was necessary to sink a pump, to a depth of about three feet below the plane of the formation, and thence to carry on a drain from the bottom, at a rise of about one in six hundred,

the least inclination on which water was found to flow, until the bottom of this drain again met the plane of the gradient, when another sump of three feet was sunk, and so the operation was repeated. The water in each sump was raised by a hand pump, to the adjoining higher drain, and so passed to the outfall referred to. By this means, the descending stretches were drained at the eastern face, and from the bottom of the various shafts, a main sump being first formed at each shaft, out of which the water was lifted, in the manner that will be presently described. The water from the ascending headings naturally fell into the sump, at the shaft's bottom.

There was no point so difficult to form a judgment upon, as fixing the power and appliances for drawing the water out of the shafts, during the process of sinking, and after they were got down. The amount of water to be met with was an unknown quantity; but, from the reasons mentioned at an early part of this paper, it was thought that pumps with working barrels, eight inches diameter, which might be worked by the twenty-five horse winding engines, would be sufficient; and accordingly this arrangement and power were provided, and although it turned out defective in some respects, which occasioned delay and expense before exhausting the springs that were occasionally encountered, it answered the purpose, except at No. 2 shaft, where it was found necessary to put in a double set of similar pumps and two engines, to overcome the water that was met with.*

* The extra space occupied by the pumps and timbers in No. 2 shaft, prevented any base larger than four feet nine inches to be transferred through the shaft, into the interior.

For the first twenty or thirty yards of the sinking, the water was raised in the usual way, by a water barrel of one hundred gallons, and a driftway was driven at about this depth, out from the shaft to the surface of the hill side, to deliver the water that should be lifted from a greater depth, when the pumps were introduced. The pumps occupied a segment of the shaft set apart for the purpose, and were supported by flanges at the joints, and the requisite horse-trees and collars, &c. as shown in Plate VII. figs 1, 2, 3, and 7. The pump-trees were nine inches diameter, in lengths of nine feet, with a ten inch wind bore and slide to adapt to the bottom, as the sinking proceeded, and to admit from time to time, another joint of the pump-trees to be added on. The wind bore was made very strong, in order to withstand the blows it received from blasting in hard measures, and the slide bore passed in through a packing box at the upper end, and being ten feet long, permitted a variation of nine or ten feet in the depth from which it lifted, so as to enable another nine feet length of pump-trees to be added on as required.

The vertical range of the shafts was divided into three separate lifts of pumps; and at the level where those lifts were broken, (as it is termed,) a chamber was excavated in at the side, 50×7×5 feet dimensions; and a puddled dam, four feet high, was raised abreast of it, and flush with the lining of the shaft. This was capable of holding from six to ten thousand gallons of water. The higher lifts were proportionately longer than the lower ones, in order to compensate for the greater weight and strain of pump rods necessary to reach to the lower lifts, from the L legs at the top of the shaft, which were worked by the engines in the manner shown in plate IX. figs. 1 and 2.

The lowest lift of pumps raised the water from the sump at the bottom of the shaft, to the first lodge, whence it was raised to the second lodge by the middle lift, and thence, by the top lift, to the near surface, and discharged through the drift already described, (see plate VII. figs. 6, 7, and 8.)

Before dismissing the subject of drainage, it may be stated that the two more westerly shafts had considerably more water than those to the east side of the hill, arising probably from their position relative to the outcrop of the strata on the western escarpment, and the beds of grit being more porous, (see plate VI.)

SINKING OF THE SHAFTS.

The process of shaft sinking and drawing out the water and material, is familiar enough in the colliery districts, and the practice observed at this tunnel, did not differ materially from that in general use, so that it does not require to be minutely detailed. Shafts of three times the depth and difficulty of those in question, have been successfully accomplished; but it may not be out of place to give a short general description of the sinking, &c., to perfect the object of this paper.

The centre point being fixed, and the size of the shaft determined, it was described on the ground with a radius twelve inches greater than the nett dimensions, to admit of the sides being lined with masonry for some short distance down. The first material generally met with was a thin bed of peat, resting on gravel and loose rack, which merged into a bed of shale or sandstone, into which the sinking penetrated a few yards, before the

foundation course of the walling was laid. This was set upon a timber curb, and carried up in a regular manner. The depth to the foundation of the walling might be perhaps ten yards.

The sinking then proceeded for twenty or thirty yards without any particular occurrence; but little water was encountered, and the only means used for winding out the material was at first a windlass, and then a horse gin. After this depth, however, a quantity of water was generally met with, proceeding from a bed of open sandstone, which overpowered the lifting capacity of the two one-hundred-gallon water barrels. This, of course, stopped the sinking until the engine was got ready. In the mean time the delivery driftways before mentioned were driven, and the requisite cross beams for supporting the pumps were inserted as far down as the surface of the water in the shaft. As soon as the engine was erected, and the winding and pumping gear got into action, the water was lifted out of the shaft and the sinking resumed. The various strata, as shown on the section, were then passed through, and when a certain depth was reached, it was found expedient to break the lift of pumps as before described, and the lodges were formed in the manner stated.* When the level of the next lodge was reached, the second lift was broken, and the sinking proceeded with to a depth of three yards below the bottom of the tunnel, where a chamber was excavated nearly similar to the lodges, and capable of holding ten thousand gallons of water. In the event of any derangement of the pumping gear, this served to keep the workings dry for a few

* When possible, the lodges were driven in a bed of shale that required no puddling, except behind the dam. When in open rock, all round the sides and at the bottom, required to be puddled.

hours, by collecting the water till the necessary repairs were made.

The material being entirely beds of sandstone and shale, sufficiently solid to stand without lining, no further walling than that described was requisite, except at the lodges, where a casing of masonry, summered to the centre of the shaft, was introduced for a vertical space of five feet, to resist the pressure against the puddle dam in front of the water lodge.

Though walling was not required to retain the strata, it was, however, found necessary to sheet the sides of the shaft with inch boards, in order to conduct the water issuing from the strata at different elevations, down the sides of the shaft at back of the boards, so as not to shower on the workmen, and occasion interruptions by extinguishing the lights, &c.

The manner of fixing this sheeting was to fit a ring of elm, five inches square, round the shaft, a space being first cut out of the rock in which it was inserted, and wedged in a truly central position. This was repeated at every twelve feet of the vertical range, with occasionally an intermediate one when the rock was friable. Inch boards were then nailed to the wooden rings, having their side joints vertical and closely fitted, and of lengths so adjusted, that their ends met against each other in a butt joint, upon the sheeting rings. The shaft was thus kept dry and shapely, and the small loose particles of strata were prevented from dropping from the sides, down upon the workmen.

It was also found expedient to insert, at intervals, what is termed a garland or gathering ring, (see plate VII. fig. 1.) This was somewhat similar to that described for the sheeting, being likewise five inches thick, but it was nine inches wide, with a semi-circular channel in

the upper side, three inches deep. This collected the water which flowed adhesively down the sheeting boards and the side, of the shaft, and being a little inclined to the horizon, it discharged the water at the lowest point by a pipe, into the next adjacent lodge, whence it was raised, without descending to the bottom of the shaft, from which it should be lifted at a loss of power.

It may be mentioned that the sheeting could not be carried down close upon the sinking, as it would have been destroyed by the blasting. It was sufficiently safe, however, when a space of ten or fifteen yards was left between, until the bottom was reached, when it could be carried down entirely.

The winding gear and pumping apparatus will be best understood by a reference to plate IX. figs 1. and 2. Upon the extremity of the fly-wheel shaft of the engine, was fixed a spur-wheel that drove two pitched wheels, one attached to the winding shaft, and the other on the cranked shaft that gave motion to the L legs at the top of the pit, from which the pump rods were worked. There were two verticals stacked upon the winding shaft, to guide the coils of ropes that passed from thence over a wheel on top of the head gearing of the pit, so as to hang into the shaft in the required position, and suspend the skips in which the material was hoisted, (about two tons at a time.) There was also a round rope, three inches diameter, used for raising or lowering the heavy lifts of pump-trees, and worked by a powerful capstan, acting at right angles to the winding ropes.

Trap doors were contrived over the mouth of each pit, after they were sunk to the bottom, which being hinged in halves and balance-weighted, the residuary weight was lifted by a hand-gearing, when a skip passed up or down, and the doors flew open to admit it, (see plate VIII. figs.

1, 2, 3, 4 and 5.) There were rails laid on the upper surface of the doors, and when laid down, a lurrie frame was wheeled on to them, and under the skip, to carry it away to the spoil bank.

There were two sets of guide rods, of 1¼ inch round iron, stretched vertically down the shaft from the top of the head gearing, and keyed under a beam at the bottom of the shaft, which prevented the skips from swinging about or coming in contact with each other, or with any of the shaft timbers, &c. One skip was always up when the other was down. This was arranged by coiling the ropes in opposite directions upon the verticals. The guide rods were put together in lengths of thirty feet, and jointed like the old fashioned legs of a surveying instrument. They were so strained, that when struck by a bar at bottom, they sounded like a harp string, and certain understood taps served as signal to the engine man to lower or raise as required.

The time occupied in sinking the different shafts, differed considerably.

They were all commenced in the autumn of 1839, and were sunk about thirty yards deep at the end of the year.

The sinking lingered at this stage for about six months, during which time the engines and pumping apparatus were got ready, and about July, 1840, the sinking was resumed, and continued in the different shafts with various success.

	Yds.			Yrs.	M.				
No. 1 is	186	deep,*	and occupied	3	1.	Bottomed,	29	October,	1843.
No. 2 is	192	,,	,,	4	5.	Do.	31	March,	1844.
No. 3 is	165	,,	,,	2	7.	Do.	30	April,	1842.
No. 4 is	196	,,	,,	2	3.	Do.	31	Dec.	1841.
No. 5 is	138	,,	,,	2	1.	Do.	30	October,	1841.

* The depths here expressed are taken from the bottom of the sump, below the level of the tunnel to the surface, which was in some cases artificially raised to admit a tip for the spoil when the ground was flat.

Looking at the periods and spaces of time herein set forth, it will be seen that shafts Nos. 1 and 2, took a much longer time to sink than the others. The cause of this was no doubt owing to the great quantity of water; but it is not to be supposed that the difference of time was continuously occupied in sinking. It arose from other difficulties. The work was frequently interrupted by the breaking down of the pumping machinery, and consequent delays in removing the accumulated water. It was sometimes found that the sinking tapped quantities of water that were backed among the strata, which at first overpowered the engine, but were overcome, after a few weeks, by the continued action of the pumps. The supply then became constant and limited. No. 2 shaft received a clear check of twelve months, in addition to the six months that, in common with all the shafts, were lost at the first getting to work of the engines and pumps. The water was so excessive, that a second engine and additional set of pumps had to be prepared and applied, and even this did not prevent the necessity and, of course, delay, of coffering the shaft through some heavily watered beds of rock with layers of impervious strata at top and bottom, by which means the draw from the shaft was relieved.

At No. 1 shaft, a boiler burst on one occasion, and blew the engine and bed to pieces, and it took several weeks to repair, and get the water out again.

In stating the rate of sinking, such long intervals of delay as I have mentioned, may be taken as exceptional. There were, besides, countless delays arising from ordinary casualties, which may more rationally be said to belong to the process of sinking, and viewed in this light, I am of opinion that about two yards a week would best express the general rate of progress.

The quantity of water drawn out of the shafts, while in progress of sinking, has been approximately estimated, the pumps being supposed to average fourteen strokes per minute.

No. 1	582,568	tons weight.
No. 2	699,223	do.
No. 3	399,455	do.
No. 4	306,131	do.
No. 5	400,869	do.
	2,388,246	tons.

Quantity of water drawn out of the shafts after they were sunk :—

No. 1	123,725	tons weight.
No. 2	210,686	do.
No. 3	942,431	do.
No. 4	1,027,271	do.
No. 5	1,070,398	do.
	3,374,511	tons.

The total quantity of water lifted by the pumps, during the construction of the tunnel, amounted to 5,762,757 tons, which would fill a cubical cistern of 197 yards square.

The average depth of all the shafts was five hundred and fifteen feet, but the height to which this quantity of water was raised, of course, depends upon the level in the vertical range of the shafts, from which certain portions of the water were lifted, not only during the progress of sinking, but afterwards; and from the best data that exist for forming a judgment, it must be about three hundred and fifty feet, which gives us an idea of the work performed, viz :—5,762,757 tons lifted three hundred and fifty feet high, in four years and a half. This is equivalent to 58.33 horses, working for the same period.

To conclude this part of the subject: when the tunnel was finished, the quantity of water that was continually passing away, by the two side drains at the western face, indicated a discharge of 1064 gallons per minute; the velocity being about 3.4 feet per second, and the sectional area one hundred and twenty inches; that is, two side drains, each twelve inches wide, and five deep. The discharge of the pumps from the five shafts may be taken at six hundred and sixty gallons* per minute. The difference may be supposed as the discharge belonging to the western face stretch, which was never lifted, viz., four hundred and four gallons per minute.

DRIVING THE HEADINGS.

The open excavation of the western face of the tunnel was early cleared out, and the driving of the drifts was commenced at the same time as the shafts sinking, (30th September, 1839.) But the excavation at the eastern face, was a more tedious operation, and a shaft twenty-one yards deep was soon sunk, with a view to admit the driving to proceed. Before starting, however, the water began to rise in the bottom, and no means being prepared to lift it out, the driving here was suspended until the excavation was cleared out in September, 1840. The driving from the eastern and western faces then proceeded uninterruptedly, until met by the headings driven from the shafts.

The dates at which the sinking of the various shafts reached the bottom, have been stated. After this period no time was lost in commencing to drive the horizontal

* Six pumps, working fourteen strokes per minute.

driftways in every instance. The dates at which the headings met the driving in opposite directions, together with the distance of the points of junction from each shaft, are as follow :—

								Yds.		
Between	W. Face	and	No. 1	24	March,	1843,	at	94	from No. 1	Shaft.
,,	No. 1	and	2	17	Jan.	1845,	at	203	from No. 2	,,
,,	No. 2	and	3	6	March,	1845,	at	450	from No. 3	,,
,,	No. 3	and	4	30	Jan.	1843,	at	405	from No. 4	,,
,,	No. 4	and	5	18	Dec.	1842,	at	396	from No. 5	,,
,,	No. 5	and	E. face	17	Sep.	1842,	at	986	from eastern	face.

It would be tedious to describe the various casualties which occasioned more or less delay in the course of driving each heading. It may be sufficient to say, that through the hardest material met with, three yards a week could be driven, and in the softer shales, thirteen yards a week. The rate through the various measures may be said to be seven yards a week.

It is to be observed that the cost of driving through hard or soft ground is not widely different, as it was necessary to apply settings of timber to support the latter—the price of which, and the fixing, brought up the cost as high as that of the solid rock. There were, of course, rails laid down in the bottom heading for removing the excavation, and the material of the top heading was put down through the connecting shafts into the waggons; sidings or passing places being made occasionally for the waggons, as the driving proceeded.

The communication between the tunnel and the point vertically under the shafts, was effected by lurries, worked on lateral rails, at a lower level. This was found more practicable than turn-tables, which are liable to choke in such situations.

EXCAVATION, LINING, ETC.

The widening excavation was commenced in March, 1843, at the eastern face, and at the bottom of the shafts, Nos. 3, 4 and 5, and before May, in the same year, at the western face and No. 1 shaft. At this time, No. 2 shaft had not reached the bottom, and two hundred and fifty-seven lineal yards of driftways towards No. 3, and seven hundred and forty-eight yards towards No. 1—in all, nine hundred and ninety-five yards, remained to be driven. The remainder of the tunnel, viz: four thousand three hundred yards was perforated by a double driftway, in the manner described.

The course pursued was to open a length at each shaft, and also at the two entrances of the tunnel; and where the ground was not sufficiently strong to stand, a lining of masonry was quickly inserted. Two extra faces were shortly opened in each of the end stretches, ahead of the excavations carried on from the entrances. When the shaft lengths were properly finished, two faces of work naturally opened, in opposite directions. The material was drawn out at the entrances, from all the faces of work in the end stretches; and that from the other faces was drawn up the shafts, the capacity of which, and that of the lifting appliances, set the limit to the rate of progress in the shaft stretches. Otherwise, a limited number of fresh faces of operation might have been opened, further in the driftways, as was the case towards the close, when the reach near No. 2 shaft came to be pressed, after the water was mastered by a second engine, and the remainder of the tunnel was free, on both sides, to admit of the excavated material to be taken away.

The total quantity of excavation removed from the tunnel, was 227,685, cubic yards, (forty-three cubic yards per yard forward,) of which 109,390 cubic yards were drawn up the shafts, and the remainder out at the ends.

The different qualities of the various strata did not admit of a uniform practice at each face. In places where no lining was required, the top driftway was widened, and the part between the upper and lower drifts knocked out. The haunch of the arching was then formed, and the excavation got down, and the sides trimmed in lengths of ten or twenty yards at a time. Where beds were so friable as to require supporting to admit the lining, the usual course was pursued of opening in at the crown and inserting, down on each side, the requisite sills, bars, props, &c. By resorting to lengths so short as nine feet at a time, security was insured. Between these extreme qualities of strata, there were various degrees, requiring more or less of such appliances.

It required well considered arrangements to carry on all those faces of operation together, as the getting in of the requisite stone, mortar, and timber, &c. in so limited a space, was necessary, as well as removing the excavated material.

There were arches left on the north side, under the springing level, ten feet span and six feet deep, every two hundred yards of the length, to facilitate the construction of the second tunnel.

The tunnel was lined throughout, except about three hundred yards. The thickness of the lining was generally eighteen inches; but in weak ground at certain places, it was frequently increased to three feet, and

sometimes more. The character of the masonry was blocking course, for the side walls, made with hammer-dressed sandstone got in quarries about the hill, and some in the tunnel. The arching was of flat-bedded reap stones of the same description, worked in as bricks, in six inch courses, and bonded together as the rings overtook. The entire was set in common hydraulic mortar, and cost about sixteen shillings per cubic yard.

It would exceed the object of this paper to extend these remarks much farther.

The cost of the double driftway was about £7. 10s. per lineal yard, including the air holes that connected them at intervals. The sinking of the shafts cost £48. per yard, but the engines and pumping apparatus were to the good for the horizontal work afterwards. The completed tunnel cost £38. a yard forward, or £201,210.

It was opened for public traffic, 23rd December, 1845. and it may be said to have occupied six years in constructing.

[January 9th, 1849.]

An Account of some Experiments on the Strength of Models of Timber Lattice Beams; by WILLIAM FRASER, ESQ., Member.

IN the latter part of the summer of 1848, I had occasion to construct, (in connexion with the drainage operations carried on by the Board of Public Works in the Borris-in-Ossory District,) an accommodation bridge over the River Nore, at a place where the channel is about seventy feet in width at the flood water line, and but a few perches below its junction with the River Delour, a mountain torrent, which, in a course of but ten miles in length, unwaters about 26,000 acres of the southern face of the Slieve Bloom Mountains. Some idea of the force with which the floods of this torrent descend, may be formed from the fact, that during the great floods of August, 1846, the water, near the site of the proposed bridge, was observed, after six hours' heavy rain, to rise fifteen feet in about two hours.

Anything, therefore, in the form of a stone pier, or bay of piles, in the water way was objectionable; one stone arch would have been too high for the approaches, and too expensive, as there is no good rubble quarry in the immediate neighbourhood; and the span proposed, (fifty feet,) was considered too great for an ordinary girder bridge—thus, for these reasons, a timber lattice was fixed upon as the most suitable; but, when I set about preparing a design; so many questions arose regarding the depth of the lattice, scantlings of the various parts, best arrangement of the lattice bars, &c. &c., that I found it beyond my powers of calculation to arrive at any satisfactory result regarding the strength; and in the books

of reference to which I had access, there was nothing to guide me in the investigation—nothing more than the most general information as to the most remarkable of such bridges which had been already erected, and these were works of such magnitude, that descriptions of them were not immediately applicable to what I required. From the best information within my reach, certain dimensions were, however, fixed upon, but their ultimate strength arranged in a structure so complex, appeared so uncertain, that I resolved to test it by direct experiment on models similarly constructed, and bearing a certain proportion to the dimensions of the proposed bridge.

Although these experiments were enough to prove the sufficiency of the dimensions adopted for the proposed bridge, still I do not consider them numerous enough to determine the relative strength of lattice beams of different sizes, the best arrangement of the lattice bars, nor the law of stability of such structures. Therefore, in offering the results of these experiments to the Institution, the utmost I hope to effect is, to draw towards a subject so interesting, the attention of some who are more conversant with mechanical experiments than I am, and who may have more ample means of prosecuting them.

Three models were at first constructed; one, six feet three inches; one, twelve feet six inches, and one twenty-five feet in span, being respectively, an eighth, a fourth, and a half of the span of the proposed bridge; to which, in all respects, the other dimensions bore the same proportions fixed upon for the original design.

The disposition of the materials, and the scantlings in the first three models, were as shown in plate X. fig. 1.

From the first, it appeared very necessary to prevent the beams from buckling; and keeping this in view, they were broken in the following manner.

See plate XI. figs. 4 and 5. The same letters have reference to the same parts:—An iron strap (A) was made to fit closely around the lattice beam, and from the under part of it was suspended the scale pan for holding the weights. Across the top there was a strong iron plate, (B) between which, and the top of the lattice beam, a curved piece of timber, (C C) about six inches long, was inserted, to prevent the timber in the upper string piece from being wounded by the edges of the iron plate. This strap and the scale pan, as shown in the sketch, were suspended from the centre of the beam. In putting in the weights the utmost care was observed to prevent momentum.

Figure 7 thus shows the means adopted to prevent the beams from buckling. A A were two upright pieces of timber, nailed to the sole plate, (B B) and secured by the struts, (C C.) The whole was steadied by weights placed upon the sole plate. The lattice beam passed between these two uprights, the space being just sufficient to admit the beam easily; and the rubbing surfaces were soaped, to reduce the friction. There were four of these contrivances to each of the models 1 and 2, and to prevent the friction against them, from having any effect in supporting the beam, they were, upon each addition to the weight, moved back and forward longitudinally, in which direction they could be sprung to the extent of two or three inches. This arrangement was considered too weak to prevent buckling in model No. 3, which was therefore placed between two balks of timber.

The beams were supported at the ends, upon a piece of three-inch plank made fast to the face of one of the contrivances for preventing buckling (see fig. 6.) Care was taken to prevent the piece of plank from sinking with the weight,

and a loose wedge was inserted between the beam and the side of the opening, to preclude lateral motion; but it was eased from time to time, to prevent it from having any effect in keeping the beam from altering its form when the weights were applied.

The timber for all the models was cut out of the same balk, and care was observed to select pieces as equal as possible in grain and quality.

I have been thus particular in describing the circumstances attending these experiments, as I believe the results of such investigations are much influenced by the mode in which they are conducted.

The dimensions of model No. 1 were as follow:—

	Feet.	Inches.
Total length, ...	7	2
Ditto between supports, ...	6	3
Depth of beam from top of the upper string piece to the bottom of the lower, ...	0	$8\frac{1}{4}$
Depth of beam between centre of pegs, ..	0	$7\frac{1}{8}$
	Inches.	
Three single string pieces, each	$1\frac{1}{8} \times 0\frac{5}{16}$	
Lattice bars, each	$0\frac{5}{8} \times 0\frac{3}{16}$	
Horizontal distance between the centre of the pegs, ...	0	$0\frac{5}{16}$
Vertical angle of lattice, ...		73°

The vertical angles in these three models were the same, and in all other respects the dimensions of No. 2 were double, and the dimensions of No. 3 were four times those of No. 1.

Model No. 4 was first put together with oak pegs one-eighth of an inch in diameter, (as it was intended to use oak pegs, one inch in diameter, in the proposed bridge,) but, when the beam was weighted with about 60 lbs., most of these pegs gave way; it was then put together with pegs of iron wire of the same diameter.

EXPERIMENT ON MODEL No. 1.

Number.	Incremental Weights in lbs.	Incremental Deflection in inches.	Total Weight in lbs.	Total Deflection in Inches
1	65	.25	65	.25
2	56	.40	121	.65
3	56	.60	177	1.25
4	28	.30	205	1.55
5	28	..	233	Broke.

There was nothing particular observed in the breaking of this model.

MODEL No. 2.

	Feet.	Inches.
Total length, ...	13	0
Length between support, ...	12	6
Depth of bar from top of upper string piece to bottom of lower, ...	1	$4\frac{1}{2}$
Ditto between centre of pegs, ...	1	$2\frac{1}{2}$
	Inches.	
Three string pieces, each	$2\frac{1}{2} \times \frac{5}{8}$	
Lattice bars, each, ...	$1\frac{1}{2} \times \frac{3}{8}$	
Vertical Angles, ...	73°	

Number	Incremental Weight in lbs.	Incremental Deflection in Inches.	Total Weight in lbs.	Total Deflection in Inches.
1	224	.40	224	.40
2	112	.37	336	.77
3	112	.68	448	1.45
4	112	.82	560	2.27 2.55
5	56	.73	616	3.00

When 560 lbs. had been on for a few minutes, the weight was removed, when the beam instantly returned to within .65 of its original straight line, and in about three minutes it returned almost to its first position.

560 lbs. were again put on, when the deflection in-

stantly became 2.27, (what it had been) and in a minute it settled at 2.55.

When 616 lbs. were on for about four minutes, the pegs gave way; those near the centre breaking across, and those near one extremity drawing. None of the string pieces or the lattice bars were broken, but some of them were slightly strained.

The oak pegs were then removed, and iron pegs of the same diameter substituted. The beam was turned upside-down on the supports, and again submitted to experiment. The result was as follows:—

Number.	Weight.	Deflection.	Total Weight.	Total Deflection.
1	224	.50	224	.50
2	112	.50	336	1.00
3	112	.47	448	1.47
4	56	.35	504	1.82
5	56	.48	560	2.30
6 } 7 }	56	.55	616	2.85
8	28	.20	644	3.05
9	28	.35	672	3.40
10	28		700	Broke.

Soon after 700 lbs. being put on, the beam began to descend slowly, and in about two minutes broke. The string pieces were all broken in the middle; the top piece being crushed, and the bottom one torn asunder. A few of the lattice bars only, near the centre, were broken or injured; but many of the pegs were drawn.

As this model had been subjected to two series of experiments, the result was considered unfavourable; and another was therefore constructed of the same dimensions, and put together with iron pegs, as before. The result was:—

Number.	Incremental Weight.	Incremental Deflection.	Total Weight.	Total Deflection.
1	211	.40	211	.40
2	112	..	323	
3	112	.35	435	.75
4	112	.50	547	1.25
5	56	.25	603	1.50
6	56	.50	659	2.00
7	56	.25	715	2.25
8	56	.62	771	2.87
9	56	.53	827	3.40
10	28	.50	855	3.90
11	28	..	883	Broke.

This model was constructed with much care, and in the breaking of it more attention was paid to keep it from buckling, than to the other models, which would probably have borne a little more, had they been as carefully preserved from buckling.

This model broke immediately on the last weight being added; so that under all the circumstances, 883 lbs. may be taken as its maximum breaking weight.

MODEL No. 3.

Put together with Oak Travails, $\frac{5}{8}$ diameter.

	Feet.	Inches.
Total length, ...	28	0
Ditto between supports, ...	25	0
Depth of bar from top of upper string piece to bottom of lower, ...	2	9
Ditto between centre of pegs, ...	2	$4\frac{1}{2}$
	Inches.	
Three string pieces, each	$4\frac{1}{2} \times 1\frac{1}{4}$	
Lattice bars, each	$2\frac{1}{2} \times 0\frac{3}{4}$	
Vertical Angle, ...	73°	

Number.	Weight.	Deflection.	Total Weight.	Total Deflection.
1	610	.50	610	.50
2	336	.29	946	.79
3	171	.21	1117	1.00
4	236	.38	1353	1.38
5	316	1.01	1669	2.39
6	224	.61	1893	3.00
7	224	.50	2117	3.50
8	224	1.43	2341	4.93
9	56	.52	2397	5.45
10	112	.54	2509	6.09
11	112	.16	2621	6.25
12	284	1.94	2905	8.19
13	56	.31	2961	8.50

There was nothing remarkable in the manner in which this model broke; when the last weight was put on, it descended slowly, and broke fairly.

Whilst the foregoing experiments were being made, it was apparent that the disposition to buckle was in some degree owing to the lattice bars being on the outside of the string pieces, which also seemed to account for the partial drawing of the pegs in every instance; besides, in breaking, the string pieces were the first to give way, sometimes long before the lattice bars were much injured. This suggested the idea of making the string pieces stronger; but subsequently it was determined to leave them of the same scantling, but to make them double, and place them on the outside of the lattice bars.

I therefore had three other models made, in which the lattice bars were arranged similarly to those in the first series, except that at their intersections; they were laid

close together, and connected by double string pieces, as shown in plate XI. fig. 2.

Model No. 1 was put together with new pegs one-eighth of an inch in diameter; 2 and 3 with iron pegs, a quarter of an inch in diameter. In this series the spaces between the supports were—

	Ft.	In.
No. 1,.....	6	3
No. 2,.....	9	4½
No. 3,.....	12	6

It would have been more satisfactory had the lengths of these models been the same as those of the first series; but when I first set about these experiments, I intended to break three models only; and as I had to build a considerable number of accommodation bridges of about twenty-five feet in span, I broke one beam of that size to know its absolute strength. It was, however, too large to be continued in any further experiments; and hence the adoption of the dimensions stated above. The scantlings of the lattice bars and string pieces were in direct proportion to the lengths; that is, the dimensions of No. 3 were in all respects double those of No. 1, and those of No. 2 were exactly a mean between them. The mode of experimenting was the same as before described, and the results were as follow:—

MODEL No. 1, Second Series.

DIMENSIONS THE SAME AS THOSE OF NO. 1, FIRST SERIES.

Number	Weight.	Deflection.	Total Weight.	Total Deflection.
1	14		14	
2	56		70	
3	56	.20	126	.20
4	56	.17	182	.37
5	56	.20	238	.57
6	56	.38	294	.95
7	28	.22	322	1.17
8	28	.30	350	1.47
9	14	.53	364	2.00
10	07	.15	371	2.15
11	4	..	375	Broke.

When 322 lbs. were on, a lattice bar near one end split at the top peg; but it did not seem to affect the strength of the beam.

When 364 lbs. were on, a lattice bar near the centre split at the top peg; and with 371 lbs. another near the centre, split at the bottom peg.

The beam broke with 375 lbs., descending slowly until the top string pieces were crushed. The lattice bars near the centre were split.

MODEL No. 2, Second Series.

9 ft. 4½ in. in span.

	Feet.	Inches.
Total length, ...	10	0
Ditto between supports, ...	9	4½
Total length between top and bottom string pieces,	1	0 9/16
Ditto between centre of pegs, ...	0	10⅓
		Inches.
Three double six-string pieces, each		1 11/16 × 15/32
Lattice bars, each		0 15/16 × 9/32
Vertical Angle, ...		73°

Number.	Incremental Weight.	Incremental Deflection.	Total Weight.	Total Deflection.
1	205	.16	205	.16
2	56	.09	261	.25
3	56	.05	317	.30
4	56	.05	373	.35
5	56	.05	429	.40
6	56	1.0	485	.50
7	56	1.2	541	.62
8	56	1.5	597	.75
9	56	1.5	653	.90
10	28	.15	681	1.05
11	28	.22	709	1.27
12	14	.13	723	1.40
13	28	..	751	..
14	14	..	765	3.65
15	13	..	778	Broke.

The only thing remarkable in the breaking of this model was, that before it broke in the middle, the lattice bars near one end were torn asunder, in which case it differed from all the others.

MODEL No. 3, Second Series.

	Feet	Inches.
Total length, ...	13	6
Ditto between supports, ...	12	6
Total depth from top to bottom of string piece,	1	$4\frac{1}{2}$
Ditto between centre of pegs, ...	1	$2\frac{1}{8}$
		Inches.
String pieces, ...		$2\frac{1}{4} \times 0\frac{5}{8}$
Lattice bars, ...		$1\frac{1}{4} \times 0\frac{3}{8}$
Vertical Angle, ...		73°

Number.	Incremental Weight.	Incremental Deflection.	Total Weight.	Total Deflection.
0	..	..	112	0
1	169	.17	281	.17
2	112	.08	393	.25
3	112	.10	505	.35
4	112	15	617	.50
5	112	.15	729	.65
6	112	.20	841	.85
7	153	1.25	994	1.10
8	99	.30	1093	1.40
9	101	.50	1194	2.10
10	105	.65	1299	2.55
11	.98	.55	1397	3.10

After 729lbs. had been on for a few minutes, the weights were removed, when the beam returned to deflection .25.

With 1093 lbs. the buckling became just perceptible.

With 1397 lbs. the deflection remained for a minute or two at 3.10, then slowly increased until the beam broke.

The experiments on these three models proved that double string pieces added considerably to the strength, but still the extent of the deflection showed such a want

of rigidity in the beam, and consequently a change of form in the entire structure, that I was unwilling to adopt that form of lattice without having tested some other.

It was conceived a more rigid beam would be had by increasing the number of intersections of the lattice bars, and I therefore had three other models constructed according to figure, No. 3.

The length and scantlings of these were the same as those for the second series; but in order to *have two diamonds in depth with the same depth of beam,* we had to put the lattice bars close together, which made the openings smaller, and of different form. In the first and second series they were longer-shaped, and in this they were nearly squares. Double string pieces were put on the top and bottom, (as in the second series,) but middle string pieces were dispensed with.

These beams were broken in the same manner as the others, and gave the following results :—

MODEL No. 1, Third Series.

6 ft. 3 in. in span.

DIMENSIONS THE SAME AS THOSE OF NO. 1, SECOND SERIES.

Number.	Incremental Weight.	Incremental Deflection.	Total Weight.	Total Deflection.
1	23	..	23	..
2	56	.05	79	.05
3	56	.03	135	.08
4	56	.12	191	.20
5	56	.05	247	.25
6	28	.07	275	.32
7	28	.08	303	.40
8	28	.04	331	.44
9	14	.06	345	.50
10	14	.02	359	.52
11	14	.03	373	.55
12	14	.02	387	.57
13	7	.04	394	.62
14	7	.03	401	.65
15	7	.03	408	.68
16	7	..	415	..
17	7	..	422	.80
18	4	.03	426	.83
19	4	.07	430	.90
20	7	..	437	Broke.

This model was broken very carefully, and the result may be taken as its maximum strength.

MODEL No. 2, Third Series.

9 ft. 4½ in, in span.

DIMENSIONS THE SAME AS THOSE OF NO. 2, SECOND SERIES.

Number.	Incremental Weight.	Incremental Deflection.	Total Weight.	Total Deflection.
1	..	..	205	..
2	112	..	317	..
3	56	..	373	.15
4	56	.05	429	.20
5	56	.05	485	.25
6	56	.05	541	.30
7	56	.04	597	.34
8	56	.06	653	.40
9	56	.04	709	.44
10	56	.10	765	.50
11	56	.25	821	.75
12	63	..	884	Broke.

After 821 lbs. smaller weights were added, until 884 lbs. were on—up to this weight the deflection did not increase perceptibly until 884 lbs were on for a few minutes, whe it broke suddenly; before breaking, it seemed strained throughout its entire length. The lattice bars in the centre broke across.

MODEL No. 3, Third Series.

12 ft. 6 in. in span.

DIMENSIONS THE SAME AS THOSE OF NO. 3, SECOND SERIES.

Number.	Incremental Weight.	Incremental Deflection.	Total Weight.	Total Deflection.
1	..	..	519	.27
2	108	.08	627	.35
3	63	.04	670	.39
4	56	.04	746	.44
5	56	.03	802	.47
6	56	.03	858	.50
7	56	10	914	.60
8	56	.03	970	.63
9	56	.07	1026	.70
10	56	.05	1082	.75
11	56	.05	1138	.80
12	56	.07	1194	.87
13	50	.06	1244	.93
14	50	.07	1294	1.00
15	28	.08	1322	1.08
16	28		1350	
17	22	.07	1372	1.15
18	24		1396	
19	16	.20	1412	1.35
20	12		1424	
21	14		1438	
22	14	..	1452	Broke.

When about 1200 lbs. were on the beam, it was very difficult to keep it from buckling; and, in the end, it buckled unexpectedly in the middle, and broke before its full breaking weight was upon it; but it evidently would not have borne much more.

All these models buckled and broke in nearly the same way, which I will endeavour to describe.

Until nearly the time of breaking, the top of the beam presented two straight lines dipping towards the centre,

where they were connected by a short curve. The bottom and middle string pieces were not parallel to the upper, being much less depressed in the centre, so that from the commencement of the experiment, the depth of the beam at the centre, became gradually less. Just before breaking, a short space in the centre, and on the top, became depressed, buckled to a great extent, and then broke; the top string piece breaking first, then the middle, and last of all the bottom string piece.

The lattice bars were curved from top to bottom, the curve being in opposite directions at opposite ends of the beam. In model, No. 3, (first series) when 2,397 lbs. were on, the versed line of this curve was three inches. The lattice bars being curved in different directions on both sides of the centre, occasioned a displacement in the parallelism of the pegs; one half of the top row dipped towards the horizon in one direction, the other half in the contrary direction, but both on the same side pointed towards the centre. The bottom row of pegs was just the reverse of the top row, being parallel to one half of the top row on the other side of the centre; and in direction, the middle row of pegs occupied a position about a mean between the top and bottom. The centre pegs in all the rows retained their original position.

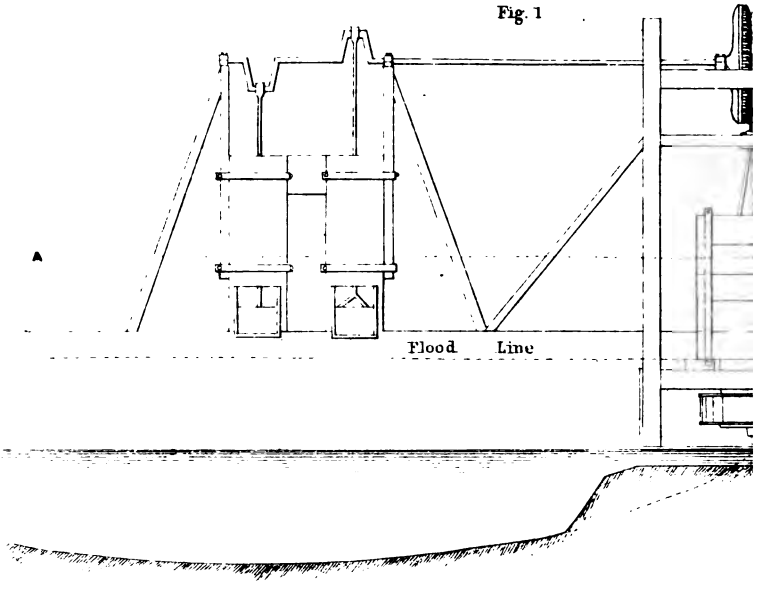
The plan of the top of model, No. 3, when 2,397 lbs. were on, was as shown in figure No. 8, plate XI.

The following table shows the results of the experiments in a condensed form :—

No. of Model.	Length of Model between supports.	Quantity of Timber, Cubic Inches	Breaking Weight in lbs.	Total Deflection in Inches.	Relation of the Deflection to the length between the supports.	OBSERVATIONS.
	FIRST SERIES. THREE SINGLE STRING PIECES, ONE DIAMOND IN DEPTH.					
	Ft. In.					
1	6 3	130	233	1.55	$\frac{1}{48}$	A very fair experiment; second time experimented on.
2	12 6		700	3.40	$\frac{1}{35}$	Very carefully broken; this is its maximum weight.
	12 6		883	3.90		
3	25 0		2961	8.50	$\frac{1}{35}$	Fair experiment.
	SECOND SERIES. THREE DOUBLE STRING PIECES.					
1	6 3	222	375	2.15	$\frac{1}{35}$	A Fair Experiment.
2	9 $4\frac{1}{2}$		778	3.65	$\frac{1}{30}$	A Fair Experiment.
3	12 6		1397	3.10	$\frac{1}{48}$	A Fair Experiment.
	THIRD SERIES. TWO DOUBLE STRING PIECES, TWO DIAMONDS IN DEPTH.					
1	6 3	184	437	.90	$\frac{1}{85}$	A Fair Experiment.
2	9 $4\frac{1}{2}$		884	.75	$\frac{1}{149}$	A Fair Experiment.
3	12 6		1452	1.35	$\frac{1}{111}$	Would have borne more.

Although the results of these experiments indicate two or three general laws, I consider them too meagre to admit of anything very satisfactory being deduced from them; I will therefore leave them for the present as they are; but as I intend making some further experiments, I shall probably on some future occasion be enabled to lay more satisfactory results before the Institution.

Fig. 1



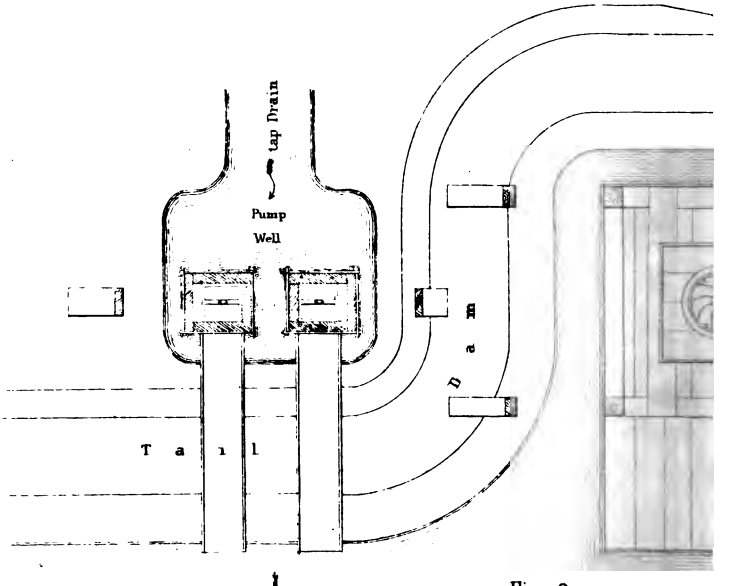


Fig. 2

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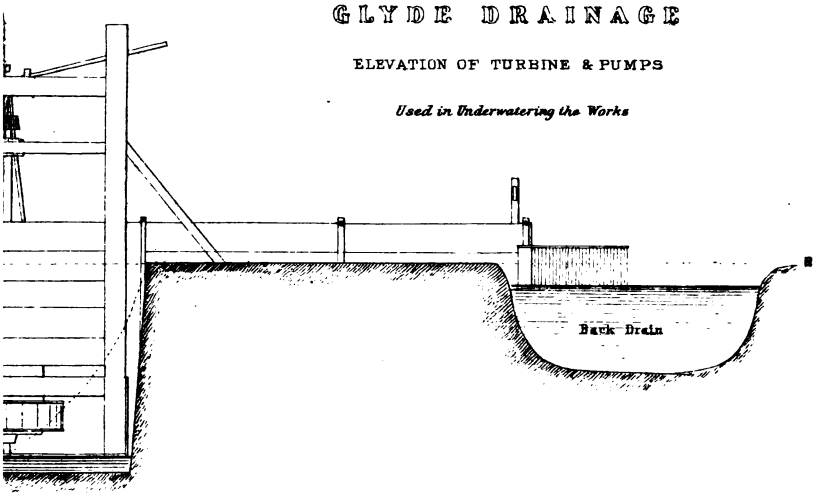
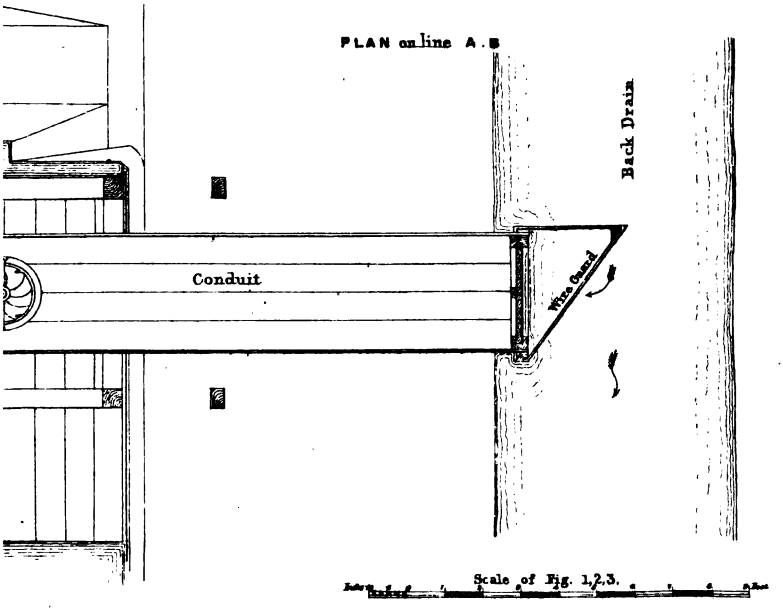
GLYDE DRAINAGE

ELEVATION OF TURBINE & PUMPS

Used in Underwatering the Works





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Forster Lith. & Co.

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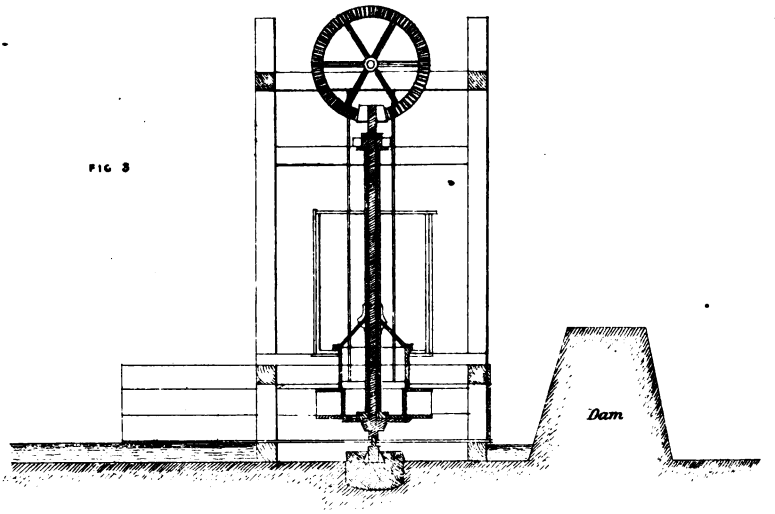
GLYDE DRAINAGE

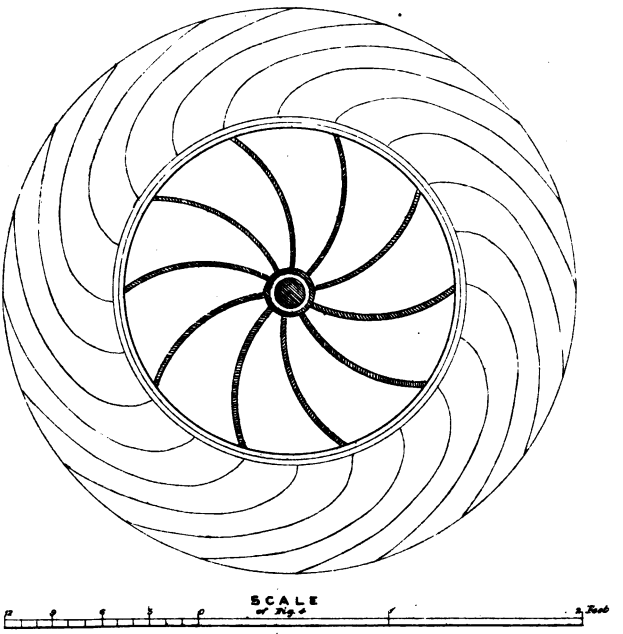
VERTICAL SECTION OF TURBINE

FIG 3



Horizontal Section of Turbine Wheel & Guide curves

FIG 4



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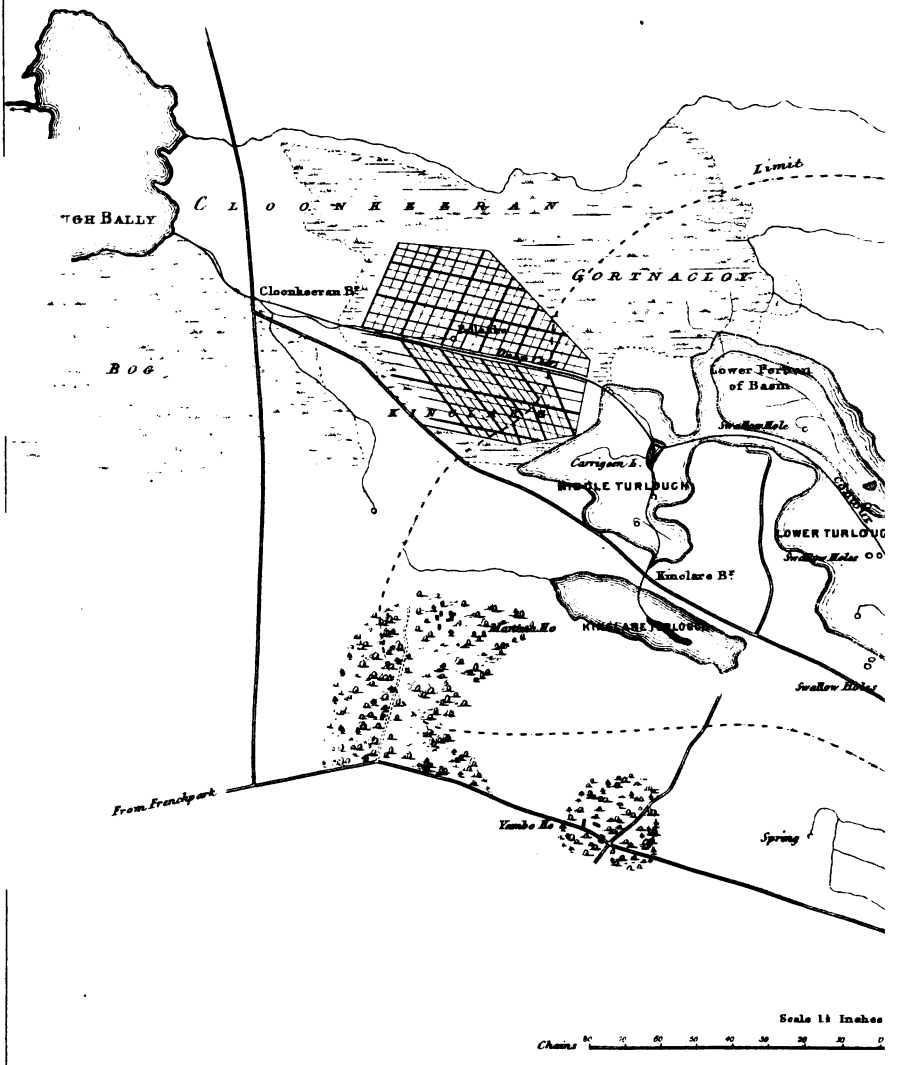

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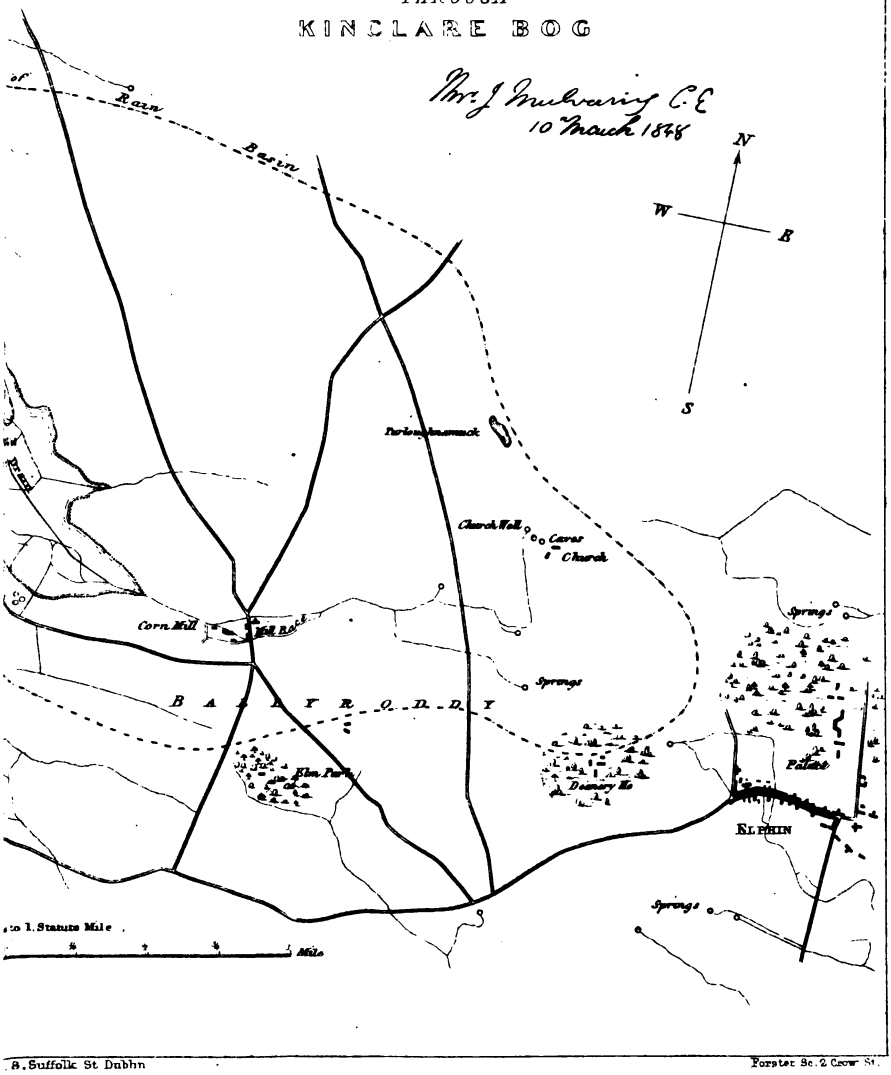
COUNTY OF ROSCOMMON

MAP OF THE MANTUA TURLOUGH'S AND THE DEEP CUT

THROUGH

KINCLARE BOG



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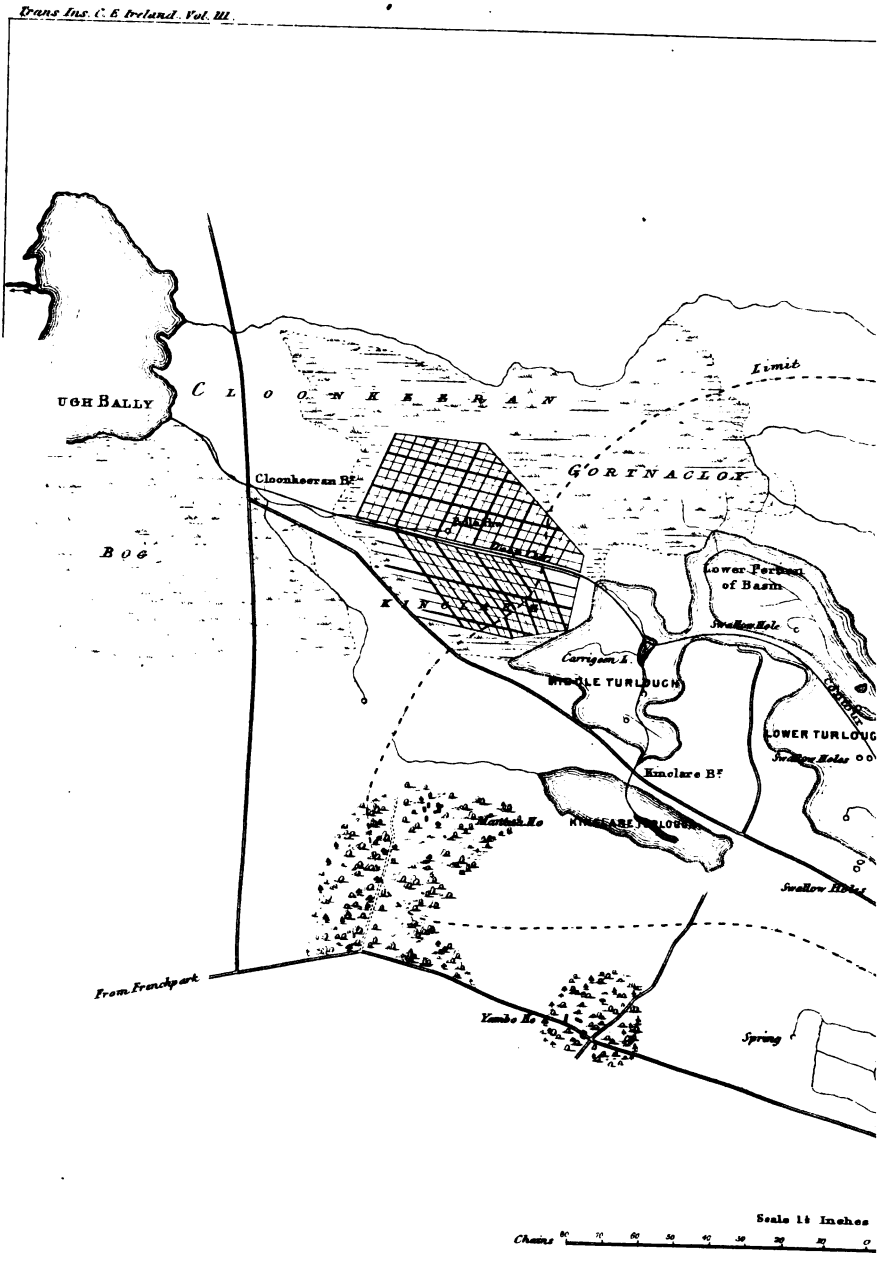

Samuel R. Oldham.

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COUNTY OF ROSCOMMON

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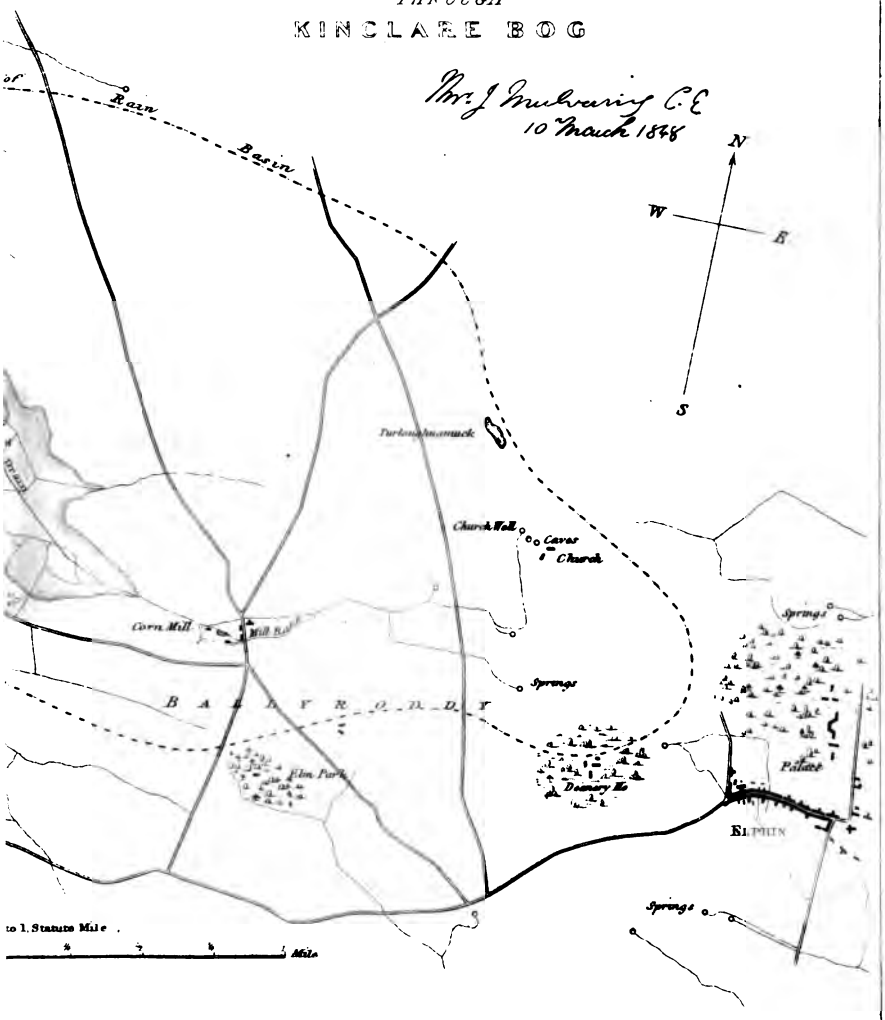
KINCLARE BOG



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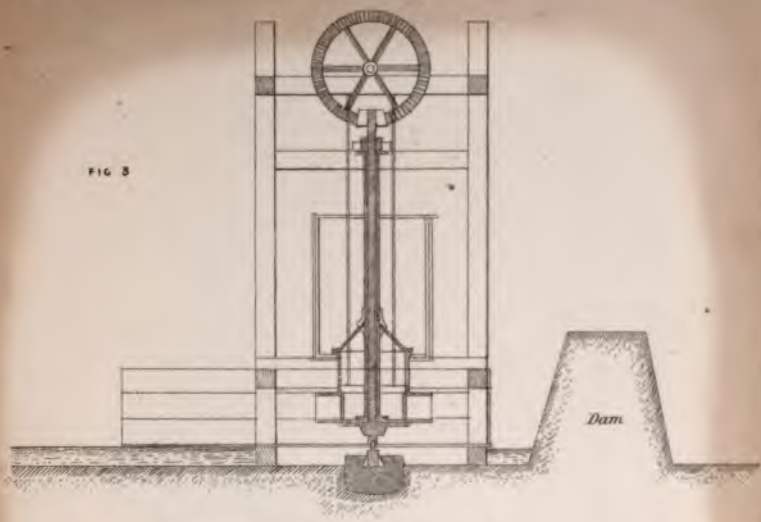
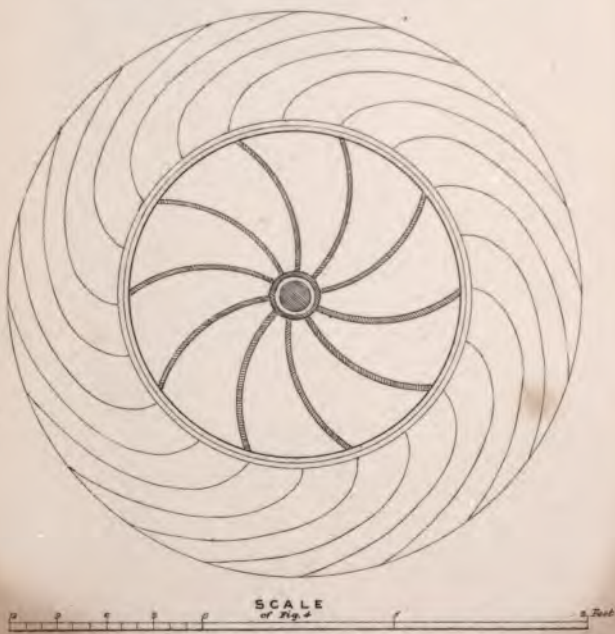
VERTICAL SECTION OF TURBINE

FIG 3



Horizontal Section of Turbine Wheel & Guide curves

FIG 4



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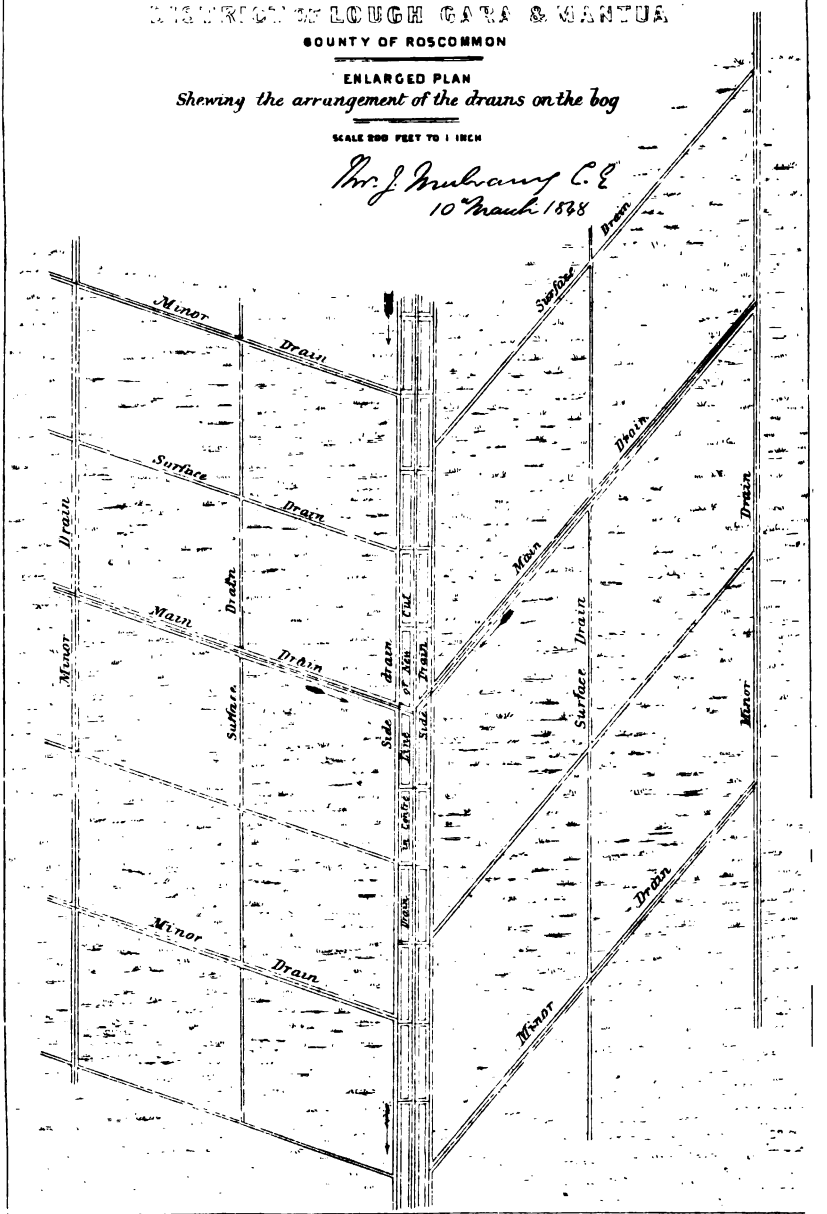
Shewing the arrangement of the drains on the bog

SCALE 200 FEET TO 1 INCH

Wm. J. Mulvany C.E.
10th March 1848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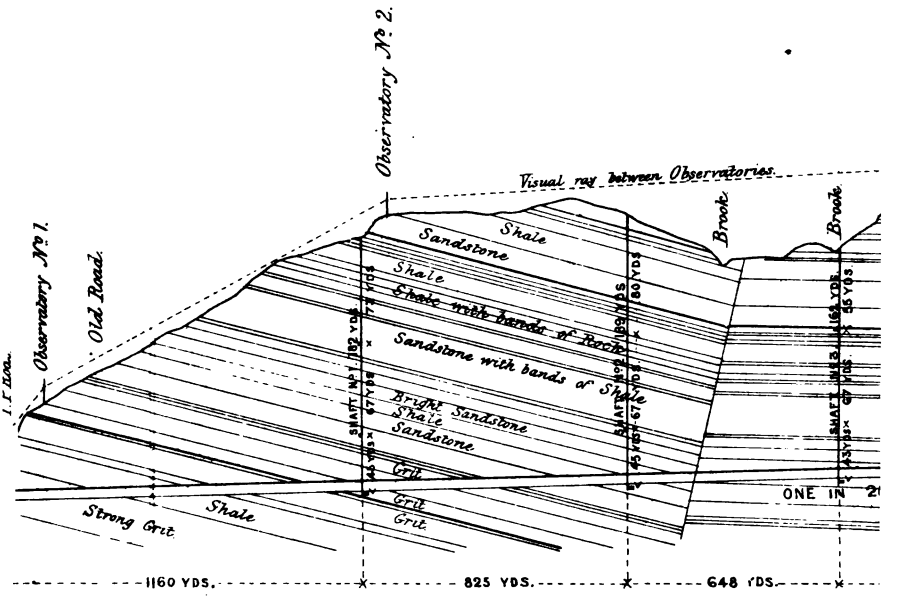
SECTION OF THE SUMMIT
ON THE LINE OF RAIL
MANCHESTER A
SHEWING THE STRATIFICATION OF T
THEIR RELATION TO THE VARIOUS LINE
By W. A. Pur



887

TOTAL LENGTH OF TUN

UM, Low Water of Spring Tides. 19

Vertical Scale 400 fe

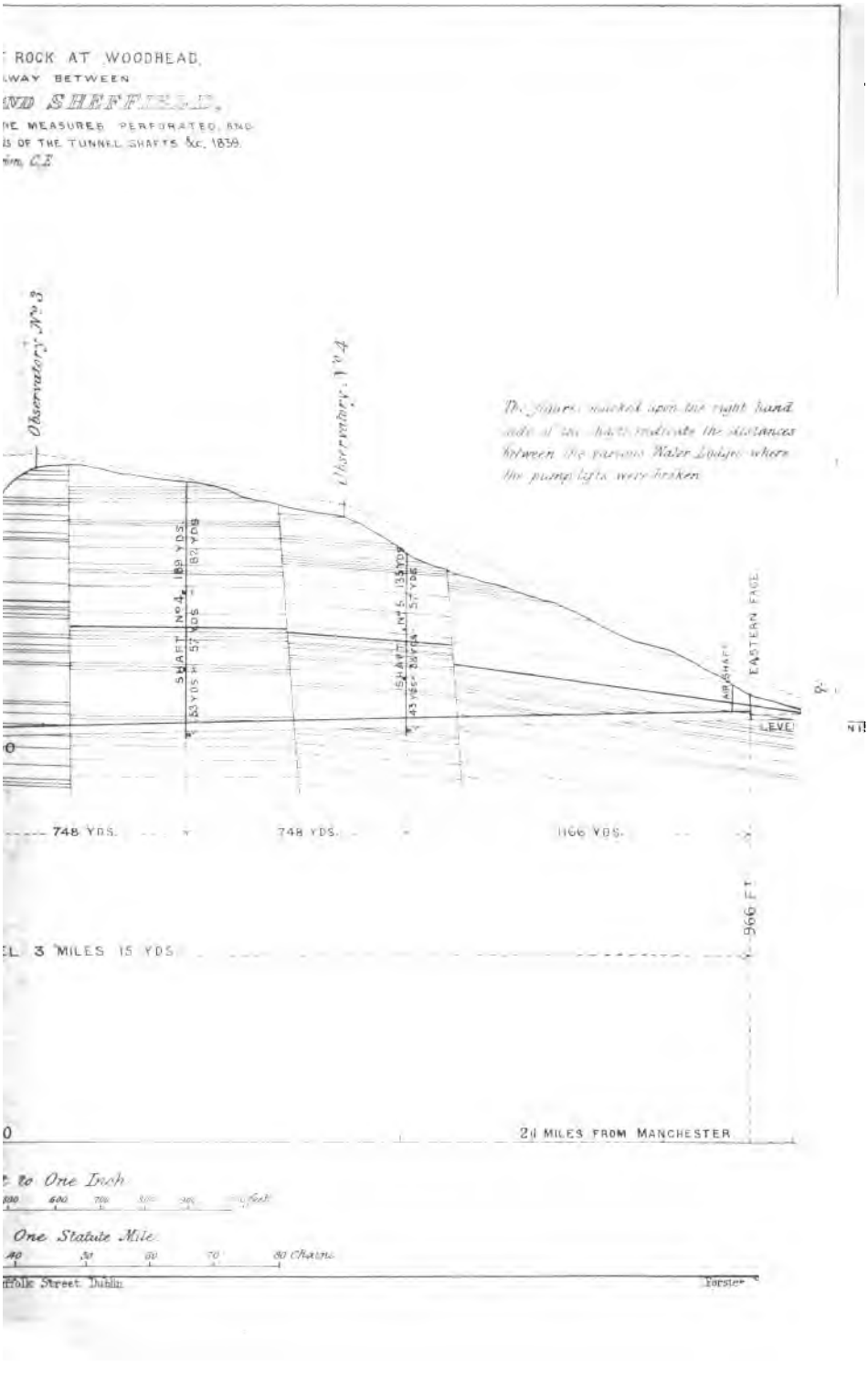
100 50 0 100 200 300 400

Horizontal Scale 3 Inches

10 5 0 10 20 30

Samuel B. Oldham, S.

Plate


ROCK AT WOODHEAD.
LWAY BETWEEN
ND SHEFFIELD.
HE MEASURED PERFORATED, AND
S OF THE TUNNEL SHAFTS &c. 1839.
Observatory No 3
Observatory No 4
The figures marked upon the right hand side of the sheet indicate the distances between the various Water Locks where the pump lifts were broken
SHAFT No 4
189 YDS.
87 YDS
57 YDS
53 YDS
SHAFT No 5
135 YDS
57 YDS
AIR SHAFT
EASTERN FACE
LEVEL
748 YDS.
748 YDS.
1166 YDS.
966 FT
EL. 3 MILES 15 YDS
0
2¼ MILES FROM MANCHESTER
to One Inch
One Statute Mile
80 Chains
Folk Street Dublin
Forster

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Shewing the arrangement of the drains on the bog

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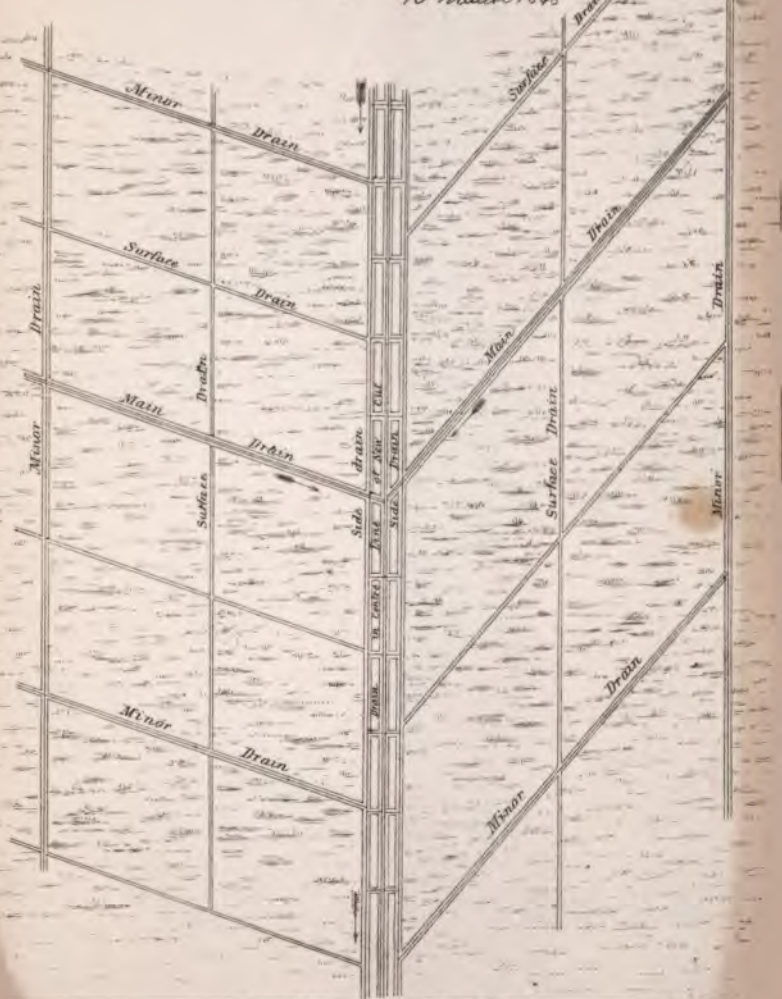
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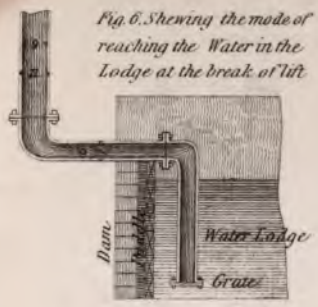

Fig. 6. Shewing the mode of reaching the Water in the Lodge at the break of lift.

Fig. 7. Horizontal Section at A.B.

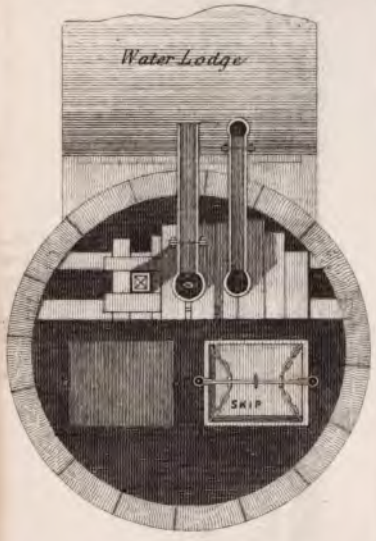

Fig. 8. Shewing the mode of discharging the Water from a lower lift.

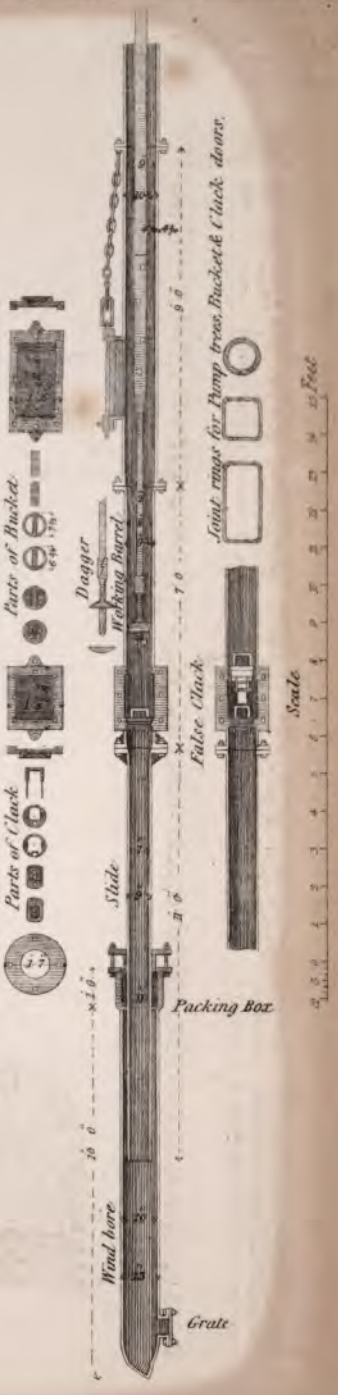

Fig. 9. Vertical Section & details of the Working Barrel, Wind bore & Slide of the bottom lift of Pumps.

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WOODHEAD

W. A. Pi

Fig. 1. Cross Section on C.D.

Fig. 2. Plan of trap doors and balance weights

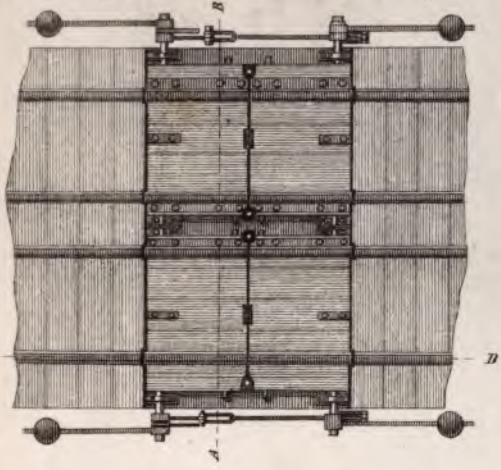


Fig. 3. Cross Section at A.B.

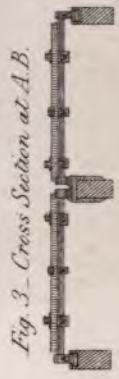


Fig. 4. Shewing the action of the balance weights

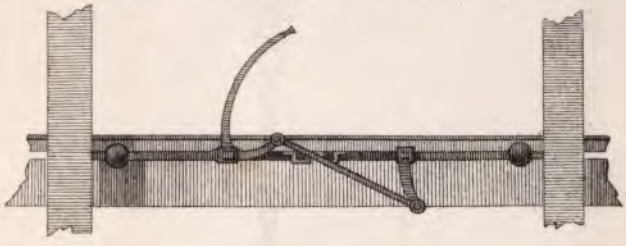
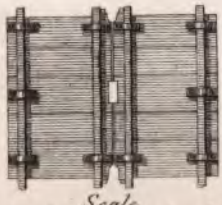


Fig. 5. Under side of trap door



Scale

12 6 0 1 2 3 4 5 6 7 8 9 10 Feet

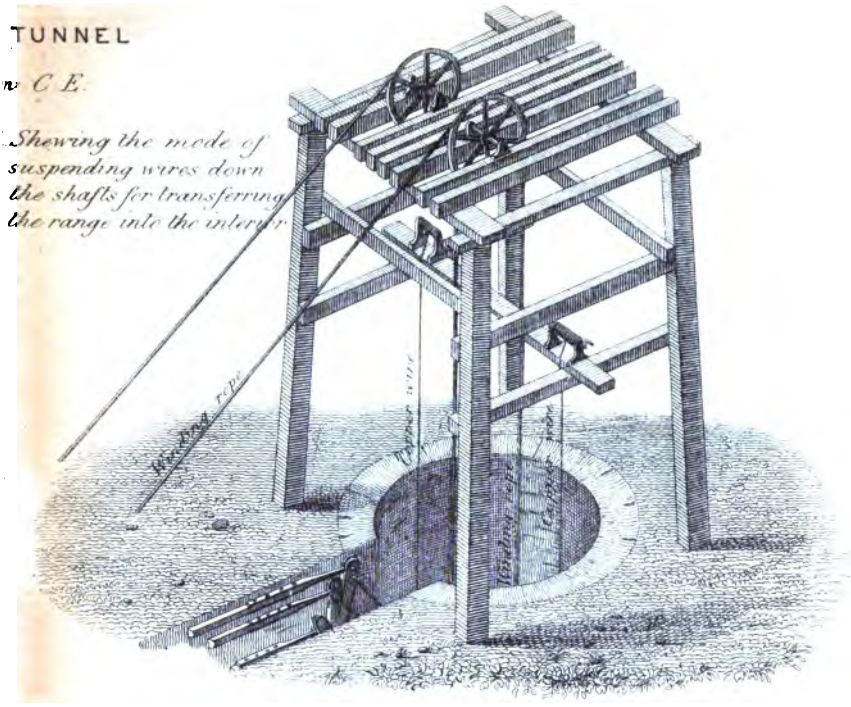
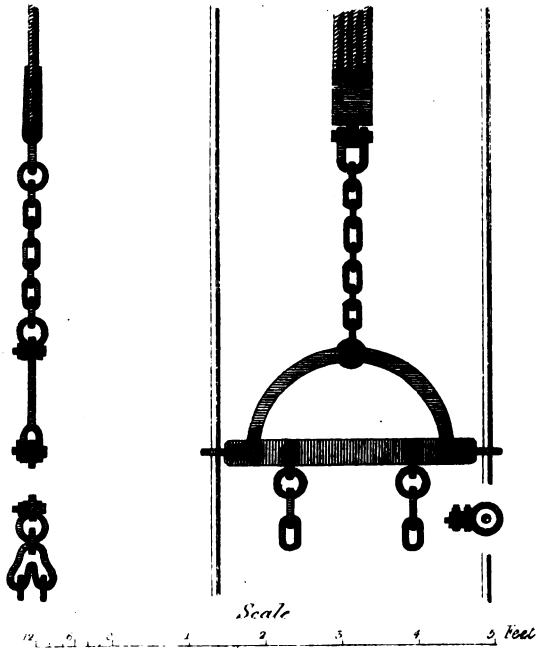


Fig. 7.. Shewing the mode of Suspending the Skips between the Guide rods



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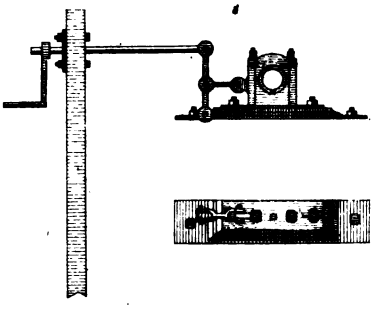
W. A. B

Fig 4. Lever for putting winding shaft in and out of gear



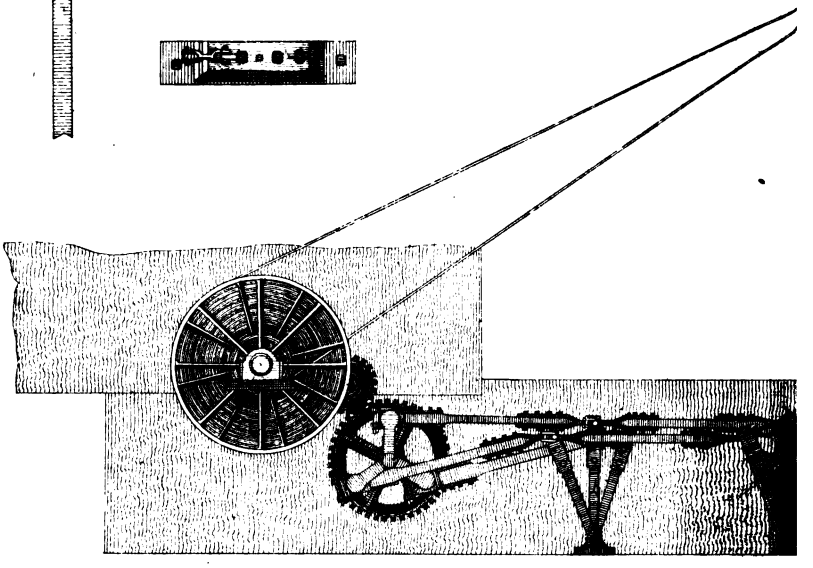


Fig 3. Plan of Verticals and Crank

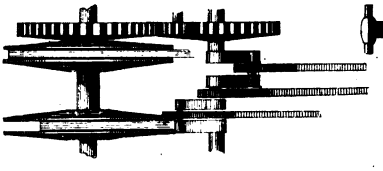


Fig 5.

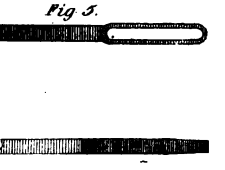


Fig 7.

D TUNNEL,
by
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Sections shewing the Head Stocks, winding and pumping gear used at the Shafts

Fig 1. At right angles to line of Railway

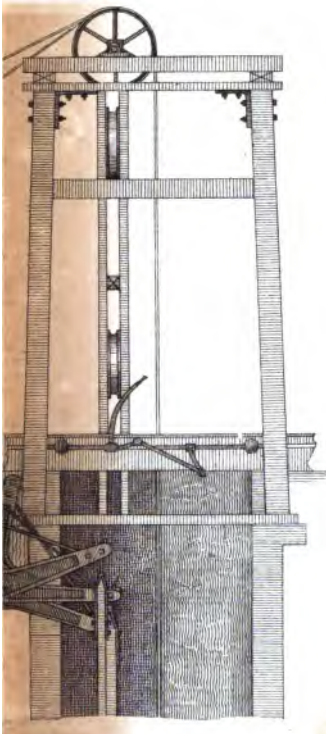

Fig 2. Parallel to line of Railway.

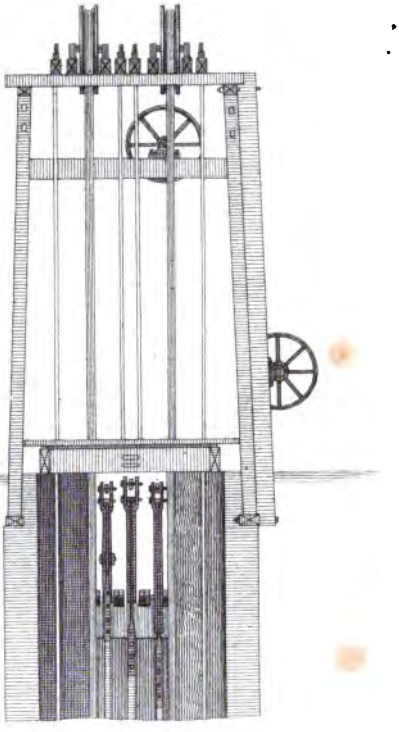

Fig 6.

Fig 8.

Scale for Figs 1,2 & 3.

5 4 3 2 1 0 5 10 15 20 Feet

Scale for enlarged plans.

12 6 0 1 2 3 4 5 6 7 8 9 10 Feet

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EXPERIMENTS ON TIMBER LA

FIG. I. *First Series.*

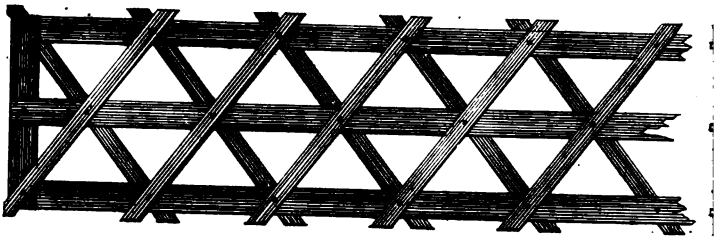

FIG. II. *Second Series.*

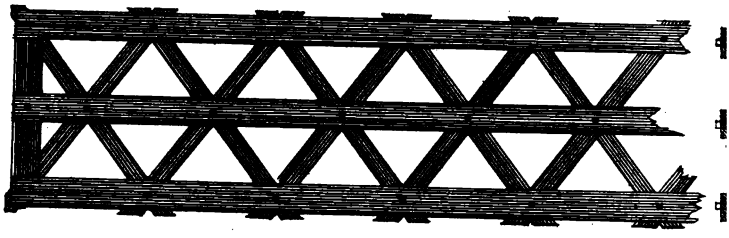

FIG. III. *Third Series.*

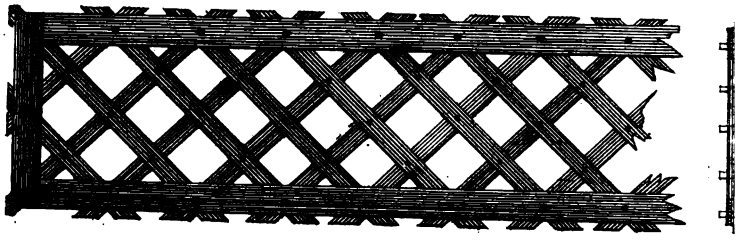

FIG. VIII.

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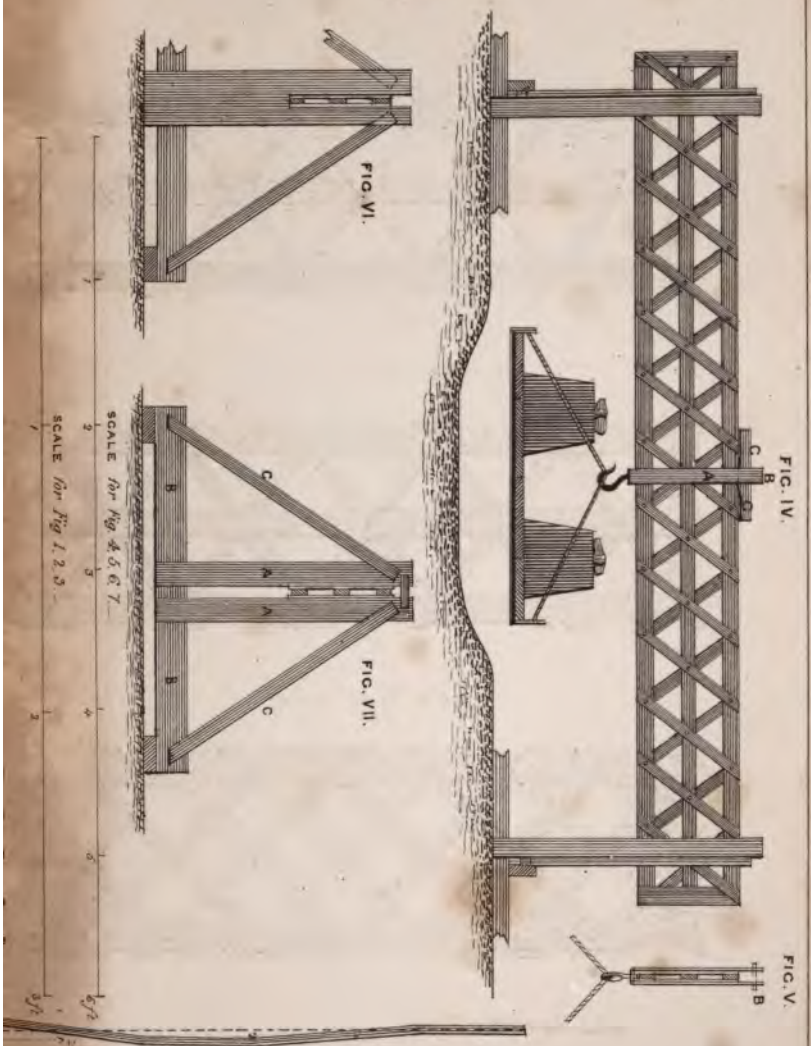

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